Philosophy vol 9.

EXPERIMENTS
AND
OBSERVATIONS
IN
ELECTRICITY.

BY

THOMAS MILNER, M.D.

> Rerum natura, ſacra ſua non ſimul tradit. Initiatos nos credimus: in veſtibulo ejus hæremus. Illa arcana non promiſcue nec omnibus patent: reducta et in interiore ſacrario clauſa ſunt. Ex quibus aliud hæc ætas, aliud quæ poſt nos ſubibit, adſpiciet.
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> SENEC. N. QUÆST. vii. 31.

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TO

THE REV. RICHARD PRICE, D.D. and F.R.S.

AND

JAMES COLLINGS, Eſq;

THESE PHILOSOPHICAL AMUSEMENTS ARE INSCRIBED,

AS A MEMORIAL OF A LONG AND

UNINTERRUPTED FRIENDSHIP,

BY

THEIR AFFECTIONATE AND OBLIGED

HUMBLE SERVANT,

THOMAS MILNER.

P R E F A C E.

THE Author has employed many of his leiſure hours in making the different parts of the apparatus, which will be deſcribed in the following treatiſe: and as he has been but little converſant with mechanical operations on any other occaſion, he can aſſure the reader, that a ſmall number of tools, and a moderate ſhare of ſkill in uſing them, will enable any perſon to make the ſame for himſelf. Five or ſix ſmall files of different ſhapes, a few drills of different ſizes, one or two ſmall ſteel broaches, a penknife, and ſome poliſhing paper, are the principal inſtruments which will be neceſſary to form all the different conſtructions.

tions. The file will give the neceſſary ſhape; the edge of the knife, by drawing it over every part of the ſurface, will remove all inequalities; and the poliſhing paper will give a proper finiſh to the whole. The laſt part of the operation will be uſeful in making a ſlender needle of ivory: for after the needle is become incapable of being conveniently reduced to a leſs diameter by the file and the knife, it may be diminiſhed to the ſize of a mere thread, by repeatedly drawing every part of from the middle to both extremities, between a folded piece of poliſhing paper, and gently preſſing it between the thumb and the fore finger at the ſame time. In this manner a ſingle horizontal ivory needle has been made two inches and three quarters long, and ſo ſlender, that the whole needle, when armed with a pair of ivory balls, weighed leſs than half a grain Troy.

Theſe little inſtruments of electricity, particularly ſuch of them as were deſigned to explain the elementary part of the ſubject, may be contained within a very narrow compaſs; and as they have now been uſed many years, they can therefore be recommended from long experience as a convenient pocket apparatus, which being always at hand, will enable the electrician at any time to ſhow ſuch an explanation of things, as may perhaps engage others to become fellow labourers with him, in cultivating the ſame field of knowledge.

Several other ſimple conſtructions, which have alſo been long employed in the ſervice of electricity, might have been added, and theſe would certainly have contributed to illuſtrate the ſubject a little, by ſhewing ſome variety in performing the ſame experiments; but as no other advantage could be derived from them, and as the experiments appear to be ſufficiently varied already, they have therefore been omitted.

The beautiful ſimplicity of the Franklinian ſyſtem procured it a reſpectful attention every where, on its firſt publication: and as it was at the ſame time well ſupported by experimental evidence, and is now almoſt univerſally received, after an examination of between thirty and forty years; this doctrine of poſitive and negative electricity, may be conſidered as a certain and well eſtabliſhed truth. It will be attempted in the following treatiſe, to illuſtrate the connexion as well as the contrariety of theſe two powers, and to enquire particularly into the nature of charged glaſs; and it is apprehended that the reſult of theſe experiments may contribute a little to the confirmation of this doctrine. Every electrician knows, that light bodies electrified negatively recede from one another in the ſame manner as when they are electrified poſitively; and that it has been attended with ſome difficulty to explain this experiment in ſuch a manner, as might be conſiſtent with the unity of the electrical fluid. Some attempt will be made to ſolve this difficulty, by conſidering what changes in the air are likely to be produced by a power of either kind: and whether the obſervations on this head ſhall appear to be ſatisfactory or not, it is recommended to the reader, to direct his inquiries to the ſame part of the ſubject, as the moſt likely means of leading him to a better ſolution, or to ſome other diſcovery.

The progreſs of the preſent age in electricity has been truely ſurprizing: but we are ſtill unacquainted with the uſes of the electrical fluid in nature. The air, the earth, in ſhort every portion of matter we can examine, appears to contain ſome of it; which therefore muſt be univerſally diſtributed through the whole material world: and from this univerſality alone we may conclude, that its uſes muſt be conſiderable in the preſent ſyſtem. Some future philoſopher will be likely to diſcover what ſome of theſe uſes are; and perhaps at the ſame time he may help to explain, how more or leſs of this fluid operates in conjunction with other cauſes, in the formation of wind, hail, ſnow, rain, and all the other wonders of our atmoſphere. It appears from the moſt deciſive experiments, that lightening and electricity are one and the ſame thing; and the *aurora borealis* may, with great probability, be aſcribed to the ſame cauſe: but we cannot ſhow by any direct experimental proof, how an electrical power is generated in nature. From theſe and many other conſiderations it is evident, that we are at preſent very imperfectly acquainted with this branch of

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knowledge, which may truly be conſidered as being ſtill in its infancy.

To inquire into the laws and operations of nature, is an employment perfectly well ſuited to the nature of man, and capable of adding real dignity to the moſt exalted ſtation. Experimental inquiry, which is the moſt ſure and certain road to truth, appears to be inſeparably connected with human nature: for the common buſineſs of the world is really a courſe of experiments, in which every individual is conſtantly employed. The mechanic, the manufacturer, the artiſt, all derive their ſkill entirely from habit, which cannot be acquired without frequently repeated trials; and the uſes of all the neceſſaries and conveniences of life are equally the reſult of experiment. ——Every rational creature, therefore, is capable of walking in ſome of the delightful paths of experimental philoſophy. Electricity in particular is within the reach of any perſon, and if thoſe who have leiſure would employ part of it on this ſubject, and encourage others to do the ſame, great improvements might then be expected: for it is reaſonable to believe, that many important diſcoveries are ready to reward the induſtry of thoſe, who ſhall carefully apply themſelves to this part of experimental philoſophy.

Maidſtone, July 1, 1783.

ERRATA.

P. 5, l. 2, 4, 16, *for* ſupporters, *read* ſupporter.
9, — 13, leave out the word ‘ conducting.’
Sect. 44, ſhould have been entitled ‘Experiment XI’ and one added to every ſubſequent experiment.
57, — 5, *for* as a glaſs, *read* as glaſs.
97, — 6, *for* electricity, *read* elaſticity.
19, *for* needles, *read* needle.

INTRO-

INTRODUCTION.

IT was apprehended, that the firſt principles of Electricity might be conveniently explained by uſing ſome needles made of different ſubſtances; ſuppoſing they were to be ſo formed as to move freely on a point, after the manner of the magnetic needle: and the purſuit of this idea has produced the following Experiments and Obſervations.

A very ſmall excited electric, weighing only a few grains, will be ſufficient to electrify ſome of theſe needles; but in moſt of the following experiments it will be neceſſary to uſe a ſmall round ſtick of the beſt ſealing-wax, which is to be excited with a woollen rubber; and a cylindrical piece of ſmooth ſolid glaſs, of the ſame dimenſions, which is to be excited by rubbing it with ſilk. No larger electric bodies are to be uſed for the preſent purpoſe; unleſs it ſhall be particularly mentioned.

Moſt of theſe experiments may be performed two different ways; with an excited electric, or with a conducting body inſulated and electrified; and therefore the obſervations, which will be made in the ſequel, muſt be applicable to an electric power in general. With regard to the different methods of performing theſe experiments, the preference is given to the immediate uſe of the excited electric, that every experiment might be ſhewn in the moſt ſimple form.

The deſcription of the different needles, and their ſeveral connexions, will be given when they ſhall be immediately wanted; and the whole may be divided into three parts.

I. Some of the effects which an electrical power is capable of producing on conducting ſubſtances.

II. Similar effects of the ſame power on electric bodies themſelves.

III. Obſervations on the air; electric repulſion; the electrified cup; and the analogy between electricity and magnetiſm.

ELECTRICAL EXPERIMENTS,

AND

OBSERVATIONS.

PART I.

Some of the Effects of an Electrical Power on conducting Subſtances.

The Construction of a ſingle horizontal Needle.

SECTION I.

MAKE a ſlender needle of ivory, or any other conducting ſubſtance, three or four inches long, and of the ſame ſize from the extremities to the middle part, which muſt be broad enough to admit of a round hole being made through it, about the tenth part of an inch in diameter, for the reception of a proper cap. The thickneſs of the heavieſt needle ſhould not exceed the twenty-fourth part of an inch, and if it be intended to make a very light needle, it muſt be reduced to leſs than half that ſize.—

——Let a cap be alſo made of ivory,* with a cavity about the eighth part of an inch deep, and the twentieth of an inch wide, and its termination ſuch, as will allow it to move freely on a point. If the outſide of the cap be made a little a little conical, and the hole in the middle of the needle which is to receive it, be opened with an inſtrument of the ſame ſhape, the one may be ſo well fitted to the other, as to require no other faſtening. Every part ſhould be made round, ſmooth, and as free from angular edges and ſharp points, as poſſible. Let a cylindrical piece of poliſhed amber, one inch and half long, and three tenths of an inch in diameter, be fixed perpendicularly in the middle of a flat round ſtand, made of a piece of cork, faſtened in a ferrule of ivory or metal. Let the upper end of the amber be rounded, and have a hole drilled into it, a quarter of an inch deep, for receiving the lower end of a ſmall rod of ivory, about two inches long, and pointed at the upper end. On this point the needle is to be mounted.

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* A cap may be eaſily made of glaſs, in the following manner.—Get a piece of glaſs tube four or five inches long, the cavity of which ſhould be about the twelfth or fifteenth part of an inch in diameter, and its ſides about the thirtieth part of an inch thick. The end of this tube may be hermetically ſealed, without the aſſiſtance of a blow-pipe, by holding one end of it in the upper part of the flame of a candle, turning it round the whole time, and taking care, that the end to be ſealed be held lower than the other. If the candle burns ſteadily, the glaſs will ſoon run, ſo as to cloſe the end entirely within a few ſeconds, and a well poliſhed concavity will be formed, of a moſt convenient ſhape for the purpoſe intended. After it is cool, mark the ſide of the tube with the edge of a file, about a quarter of an inch from the ſealed end, more or leſs, according to the depth of the cap wanted, and in that place it may be eaſily broken off. Some irregularity generally attends the breaking, which may be ſoon removed, and the bottom of the cap made both ſmooth and ſquare, by a few gentle ſtrokes of a proper file. Theſe glaſs caps muſt not be uſed in thoſe experiments which require a free paſſage of the electric fluid between the ſupporter and the needle, becauſe in a dry ſtate of the air, glaſs will prevent ſuch a communication. It was, however, thought proper to mention this eaſy way of making them, becauſe it was apprehended they might be uſeful in magnetic experiments. Melted glaſs cools with a very high poliſh, and by this method may, perhaps, furniſh a good ſubſtitute for the agate cap, which cannot always be procured.

Sect. 2. Amber* appears to be one of the moſt perfect electric bodies, and is therefore choſen for the inſulating ſubſtance: but as amber cannot always be readily procured, ſealing-wax, and other bodies of the ſame kind, will anſwer the purpoſe very well. If glaſs be employed for the inſulator, it ſhould be always covered with a reſinous varniſh, or with a coating of ſealing-wax.

Sect.

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* Clouded amber inſulates better than the tranſparent; it is alſo leſs brittle, and therefore works better under the file and drill.

Sect. 3. Suppoſing the extremities of one of theſe ſmall needles to be ever ſo well rounded, they muſt act in ſome meaſure as points; which, as is well known, are more ready to receive, or to part with the electrical fluid, than more obtuſe bodies of the ſame kind. For this reaſon, both ends of the needle may be armed with a ſmall ivory ball; and thus it may be rendered capable of receiving more of the electrical power, and of retaining it longer. It muſt, however, be obſerved, that theſe balls are not abſolutely neceſſary, becauſe even the ſharpeſt pointed needle will be found to retain enough of the communicated power without them.

Sect. 4. The accidental undulations of the air, will occaſion the needle to wander about into every poſſible poſition, whether it be electrified or not; and as theſe motions may be liable to be miſtaken, for thoſe which are intended to be ſhewn, it will be proper to guard againſt them. This may be done many different ways. If any ſmooth conducting body, not inſulated, be placed at the diſtance of an inch from one extremity of the electrified needle, it will, by its attraction, render the needle ſtationary, without deſtroying its power, and thus afford an opportunity of ſhewing how other bodies attract or repel it, without the leaſt confuſion. The ſame purpoſe may be anſwered by a ſmall ſmooth rod of ivory, faſtened horizontally on the ſupporters, immediately below the needle: or by a ſmall circle of ivory, or braſs, faſtened vertically to the ſupporters, ſo that the point on which the needle traverſes may be a little above the centre of this circle. When the needle is electrified, it will form right angles with the rod, or with the plane of the circular regulator. Other contrivances may alſo be employed; but it appears unneceſſary to enlarge on this head, becauſe the excited electric alone may be eaſily ſo managed, as to regulate every accidental motion, and give the needle any poſition that may be required.

One of theſe needles, armed with ivory balls, and mounted on its ſupporters, together with the inſulating amber and ſtand, are repreſented in fig. 1. Fig. 2 repreſents another ſupporter, conſiſting of a pointed braſs wire, fixed in a piece of turned ivory. Fig. 3 repreſents a ſtrait regulator; and fig. 4 a circular regulator of ivory, faſtened to the ſupporter. Fig. 5 ſhews one half of a differently ſhaped ivory needle, terminating in a circle; and in fig. 6 is ſhewn an ivory needle made in a ſerpentine form.

EXPERIMENT I.

Sect. 5. Let a needle be inſulated, and electrified either poſitively or negatively; and we may obſerve the following particulars; which are to be regarded as the teſt or evidence of the electrical ſtate of the needles, or of other bodies brought towards them, in any of the following experiments, and are to be repeated for that purpoſe.

1. *Any conducting body brought ſideways towards either extremity of the electrified needle, attracts it.* This part of the experiment will ſhew with certainty whether the needle be electrified or not.

2. *A power of the ſame kind as that which was communicated to the needle, repels it.* This particular is almoſt equally certain in determining whether the power be poſitive or negative: only care muſt be taken not to approach a needle weakly electrified too ſuddenly with a ſtrong power of the ſame kind; becauſe in that caſe, it will be attracted and not repelled.

3. *A contrary power attracts it.* This may alſo be of ſome ſervice in ſhewing the quality of the communicated electricity; for, notwithſtanding a needle in its natural ſtate will be attracted by a power of either kind, it will, however, be attracted at a greater diſtance, when it poſſeſſes a contrary electricity.

4. *An electric body, in its natural ſtate, alſo attracts the electrified needle.* Care muſt be taken with regard to this laſt particular, that the electric ſubſtance be in its natural ſtate. It may have acquired ſome dampneſs, from being handled, or from the atmoſphere: or it may have

retained a ſmall degree of power, from having been lately excited, and either of theſe circumſtances may be ſuppoſed to be the cauſe of the attraction. Therefore, in order to remove every doubt, let the electric body be firſt held near a pretty good fire, which will, in a few ſeconds, make its ſurface quite dry: or it will deſtroy any ſmall degree of excited power: and when it has been aſcertained by a direct experiment to be in its natural ſtate, it will be found to attract the electrified needle.

EXPERIMENT II.

Sect. 6. Let an excited electric of either kind, be brought obliquely towards one end of the inſulated needle not electrified, and it will attract that end at the diſtance of ſeveral inches. On bringing it gradually nearer, the attraction will encreaſe, as the diſtance decreaſes. Examine the ſtate of the needle at different times during the experiment, and it will appear, that no permanent power can be communicated at a greater diſtance than about half an inch. Even at this diſtance it will be but weakly electrified, and the excited electric muſt not only touch the needle, but alſo have ſome portion of it drawn along in contact with the needle, in order to communicate to it the greateſt power it is capable of retaining.

Sect. 7. The whole ſpace to which the action of an excited electric extends, is here diſtinguiſhed into two parts, a greater and a leſs. The former may be called the *Sphere of Influence*, as in every part of it the needle is attracted, without receiving from the excited electric any of its power. The latter may be called the *Sphere of Communication*, becauſe in this the needle is not only attracted, but alſo receives an electric power, and retains it after the excited electric is removed.

Sect. 8. It muſt be remembered that theſe diſtances will increaſe or decreaſe, as a ſtronger or weaker power is employed; and that they will alſo vary in ſeveral other circumſtances:— particularly as the needle is made either of a good or a bad conductor; as it has rounded or ſharp terminations; and alſo as the air is more or leſs dry. The diſtance of half an inch, mentioned in the experiment, is to be conſidered as belonging only to thoſe ſmall electric bodies, to which the preſent experiments are confined; but in any other caſe, the limit between the ſpheres of influence and communication may be aſcertained, by determining the greateſt diſtance experimentally, at which a communication can be made.

EXPERIMENT III.

Sect. 9. Let a rod of ivory, or any other conductor, reach from the ſupporter of an inſulated needle, to the table. By this the inſulation will be deſtroyed. Let an excited electric, of either kind, be fixed perpendicularly in any convenient ſtand, and brought within three quarters of an inch of one end of the needle, which will be attracted by it.—1. Approach the attracted end of the needle with a contrary power, and it will be repelled. This end, therefore, of the needle, has acquired an electric power, contrary to that which was firſt employed. 2. Approach the ſame end of the conducting needle with any conducting body not inſulated, and this alſo will repel it; becauſe the circumſtances of this body being preciſely the ſame as thoſe of the needle, (namely, a conductor not inſulated, and brought within the influence of the excited electric,) muſt neceſſarily be affected in the ſame manner as the needle itſelf, and, having acquired the ſame power, muſt therefore repel it. 3. Let the conductor, which reaches to the table, be removed, and the needle will be found to poſſeſs a pretty ſtrong degree of electricity, and of a contrary kind to that which was originally employed.*

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* A ſmall ring or ball made of any conducting ſubſtance, and ſuſpended by a ſilk ſtring, may alſo be readily brought

Sect. 10. This effect is produced by the influence of the excited body, which cauſes a part of the electric fluid, naturally belonging to the needle, to paſs along the conductor, from the needle to the table, if a poſitive power be uſed; and therefore the needle, by loſing a part of its natural ſhare, becomes negatively electrified: or from the table to the needle, if a negative power be uſed, and then the needle, by receiving an addition to its natural quantity, becomes poſitively electrified. In both caſes, the effect produced is rendered permanent, by reſtoring the inſulation before the excited electric is removed.

Sect. 11. On repeating the experiment at different diſtances, it will ſucceed in every part of the ſphere of influence; and the contrary power thus procured, will be weaker as the diſtance increaſes; ſtronger as the diſtance decreaſes; and ſtrongeſt of all, when the excited electric is brought as near as poſſible to the needle, without bringing it within the ſphere of communication.

Sect. 12. It may be objected, *that this method of procuring a contrary power, ought not to be repre-*

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brought into a ſtate of contrary electricity, by holding an excited electric at a little diſtance below it, and by interrupting the inſulation for a moment, before the excited body be removed.

ſented as being confined to the ſphere of influence; becauſe the ſame effect may certainly be produced, not only at a leſs diſtance, but even if the excited electric be in contact with the needle. In anſwer to this objection, it may be obſerved, that an excited electric will admit of ſome of its parts being weakened, while others ſtill retain their power; becauſe it is a bad conductor. Therefore, when an excited electric is brought ſo near to the needle, as to communicate to it ſome of its power, the parts to or from which the communication has been made, muſt be weakened, and the whole of the power thus communicated, will be deſtroyed by the inſulation being interrupted: but the parts next adjoining to thoſe, to or from which the communication has been made, muſt ſtill remain in force, and theſe not being within the communicating diſtance, will act as is ſtated in the experiment, and by their influence produce a contrary power.

The Construction of a compound horizontal Needle.

Sect. 13. Let an ivory needle, of the largeſt ſize before mentioned, be choſen for the principal needle; and a compound needle may be made with it, three different ways.

I. Place a ſmall light needle on a ſhort pointed wire, faſtened perpendicularly into the upper part of the cap of the principal needle.

II. A pair of ſmall light needles may be mounted on the ends of the principal needle, by placing them on the points of ſmall braſs pins, paſſing through the balls with which the principal needle is armed. When no balls are uſed, the ſupporting pins may paſs immediately thro' the arms of the principal needles, a ſmall part being left wide enough for this purpoſe at both extremities.

III. A ſmall needle may, in the ſame manner, be mounted on one end of the principal needle, and an ivory ball or ring faſtened to the other end, of a ſufficient weight to act as a counterpoiſe, and keep the whole in an horizontal poſture.

The ſeventh figure repreſents a needle of the third ſort, with unequal arms: one being nearly double the length of the other. A ſhort ſlender needle is mounted on the longeſt end, and a ring of ivory to balance it, is faſtened on the other extremity.

Sect. 14. When a compound needle is inſulated and electrified, it will appear to be in that ſtate, by the index needle forming right angles with the principal needle; and if it be diſturbed either by attraction or repulſion, it will ſoon return again into the ſame ſituation: and it will appear, whether it be ſtrongly or weakly electrified, by the quickneſs or ſlowneſs of the vibrations,

brations, before it ſettles. This compound needle is more ſteady than the ſingle needle, and not ſo liable to be affected by the accidental undulations of the air.

EXPERIMENT IV.

Sect. 15. Let a compound horizontal needle of the third ſort be inſulated, but not electrified; and let an excited electric, of either kind, be uſed in the ſame manner as in the preceding experiment, and placed within three quarters of an inch of that end which carries the counterpoiſe. 1. Approach this end of the needle with a contrary power, and it will be repelled. 2. Any conducting ſubſtance, not inſulated, will alſo repel this end of the needle. 3. Approach the index needle, which is mounted on the other extremity of the principal needle, with a conductor not inſulated, and it will be attracted. 4. Approach this index with the ſame power as that with which the experiment is made, and it will be repelled. 5. Remove the excited electric, and the needle will be found to be in its natural ſtate, and not electrified either poſitively or negatively.†

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† This experiment may be ſhewn to the greateſt advantage, by mounting the needle on an electric ſupporter, having a ſhort pointed wire fixed in its upper extremity, juſt long enough to admit of the needle's moving freely.

Sect. 16. It appears from the particulars of this experiment, that during the action of the excited electric, one end of the needle was electrified poſitively, and the other negatively; and that the end neareſt to the excited body, had the contrary electricity. Theſe effects muſt be produced, by ſhifting ſome part of the electrical fluid belonging to the needle, from one end of it to the other, and not by adding to its natural quantity, or taking any of it away; becauſe the excited electric was not brought within the communicating diſtance, and the inſulation had not been interrupted. Thus a temporary electricity, both poſitive and negative, were produced at the ſame time, by the influence of the excited electric, without any communication; and when that influence was removed, the natural quantity became again equally diſtributed: and therefore, at the cloſe of the experiment, the needle was found to be in its natural ſtate.

Sect. 17. Many circumſtances muſt be regarded in performing the laſt experiment. The atmoſphere ought to be tolerably free from moiſture, and the inſulating body in good order. Particular care ſhould be taken in approaching the different ends of the needle with the excited electrics, and conducting ſubſtances, not to bring them any nearer than may be juſt neceſſary to ſhew the attraction and repulſion, as mentioned in the experiment. It will be alſo proper to go through the whole in as ſhort a time as poſſible. By carefully obſerving theſe cautions, the needle will appear to be in its natural ſtate, at the end of the experiment, and not to have acquired any permanent electricity of either kind.

A Conſtruction, in which two horizontal Needles, having ſeparate Inſulations may be uſed at the ſame Time.

Sect. 18. Bend a piece of braſs wire into a circle, three inches and three quarters diameter. The wire ſhould be about the fourteenth part of an inch thick. Let an ivory ball, three-eighths of an inch in diameter, be perforated quite through the middle, with two holes, in a perpendicular direction to each other. The two ends of the bent wire are to be fixed in the oppoſite openings of one of theſe perforations, and a round pin of wood is to be well fitted to the other, paſs quite through it, and project beyond the ſurface of the ball about a quarter of an inch on both ſides. The lower end of this wooden pin muſt be fitted to the inſulating amber before mentioned, and the wire circle placed in a vertical poſition. Let another piece of amber, not leſs than three quarters of an inch long, be fixed perpendicularly on the uppermoſt part of the wooden pin. A light needle, one inch ſhorter than the diameter of the wire circle, is to be mounted on a pointed wire, placed perpendicularly in the upper part of the laſt mentioned piece of amber, and of ſuch a length, that the middle of the needle may coincide with the centre of the circle. Another needle of the ſame ſize is to be mounted on the outſide, and upper part of the wire circle, on a ſhort pointed wire, faſtened in a piece of ivory, which is to be fixed there for that purpoſe. See the eighth figure.

EXPERIMENT V.

Sect. 19. Apply a well-excited electric, of either kind, immediately to the lower needle, and at the ſame time let it be brought as near as poſſible to ſome part of the wire circle, without being within the communicating diſtance. In order to do this, paſs one half of the excited electric through the plane of the wire circle, and within it, as high as the centre, and about three quarters of an inch from one ſide. While it is held in this ſituation, let the wire-circle be juſt touched with any conductor not inſulated; then withdraw the excited body, and both needles will be electrified, but with contrary electricities. The lower needle will have the ſame power as the excited electric, becauſe they have been in contact; and the upper needle, together with the wire circle, will have a contrary power, becauſe the excited body, with reſpect to them, was held within the ſphere of influence, when the inſulation was interrupted. Both needles being allowed to ſettle, the lower will lie in the plane of the circle, by which it will be ſtrongly attracted: the upper having the ſame electricity as the wire circle, muſt be repelled by it, and therefore will take a quite contrary poſition: and on bringing the ſame excited electric towards the extremities of both, the upper needle will be attracted, and the lower needle repelled, at the ſame time. After exciting the ſame electric again: firſt bring its extremity ſideways towards one end of the lower needle, in order to repel it out of the circle, and then gradually ſlide it into a perpendicular poſition, on the outſide, and in the plane of the wire circle, and about an inch from it, inclining it a little towards the upper needle: and thus the excited body, when it is in full force, may be ſo managed, as to attract the upper needle into the plane of the wire circle, and to repel the lower needle, as to place it at right angles with the ſame plane: by which both theſe needles, having contrary electricities, may be made to change their reſpective directions, and without deſtroying the power of either. On withdrawing the excited electric, each needle will return again to its former direction, and this effect may be repeated ſeveral times.

EXPERIMENT VI.

Sect. 20. Let the ſame excited body, which was uſed in the former experiment, be drawn along in contact with the wire circle, and if the lower needle be touched at the ſame time, with a conductor not inſulated, then both the needles will be again electrified with contrary electricities; but the power of each will be the reverſe of what it was in the laſt experiment. For the lower needle being within the ſphere of influence, when the inſulation was interrupted, muſt have acquired a contrary electricity; and the upper needle together with the wire circle muſt have received immediately from the excited body its own proper electricity; and therefore, notwithſtanding both needles will take the ſame ſituation as before, on bringing the excited electric towards their extremities, the upper needle will now be repelled, and the lower needle attracted. The direction of the two needles cannot be abſolutely changed, by the action of an excited electric, in the preſent caſe, becauſe the upper needle and the wire circle will have a much greater degree of power than they had before, and therefore the upper needle will be too ſtrongly repelled by the wire circle, and the lower needle will be too ſtrongly attracted by the ſame, to admit of ſuch a change.

The Conſtruction of a Pair of vertical Needles.

Sect. 21. Make two very ſlender needles of ivory, about two inches and half long, having one end a little heavier than the other, and a ſmall round hole drilled through the middle of each. Let a piece of ivory, three inches and a half long, two twelfths of an inch broad, and one twelfth thick, be pierced quite through with a groove, which muſt be a little longer than the needles, and wide enough to allow them to move freely in it. The needles are to be connected with the middle of this frame, and within the groove, by a ſmall braſs pin paſſing thro' the needles, and both ſides of the frame. This pin is the axis on which the needles ſhould move freely. Another pin muſt paſs through both ſides of the frame, towards the bottom of the groove, and between the heavy ends of the needles, in order to regulate their motion. Let the lower part of the frame be ſo faſhioned, that it may ſtand perpendicular in the inſulating piece of amber. The upper part of the frame may be turned in the ſhape of an acorn, having a ſmall hole drilled into the top, for the reception of one end of a ſmall braſs wire bent into a ſemicircle, the other end of it being formed into a loop, in which a ſmall ring of the ſame wire ſhould hang looſely. Let the whole be well rounded and ſmoothed. A pair of needles made according to theſe directions weighed half a grain Troy, and the frame together with the axis, regulating pin, and communicating wire weighed fifteen grains. See the ninth figure.*

Sect. 22. The whole of the needles thus mounted and inſulated, will be contained within the groove, as long as they continue in their natural ſtate; but they will come out of it as ſoon as they are electrified. If a ſmall degree of elecricity be given to them, they will ſeparate a little, but more on receiving a greater degree, and on communicating to them the greateſt power they are capable of retaining, in the moſt favourable ſtate of the atmoſphere, they will recede ſo far from each other as to form an angle of 130 degrees.

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* This pair of needles may alſo be ſuſpended by a ſilk ſtring paſſing through the upper part of the groove, and thus become inſulated. Another method of mounting a pair of needles, is ſhewn in the tenth figure, where the axis of the needles paſſes through a ſmall round ball, by means of which they are faſtened vertically on the top of a ſlender rod of ivory, the other extremity being left of a proper ſize to admit of its being inſulated, either by the ſame piece of amber as before, or by a ſilk ſtring paſſing through a hole made for this purpoſe in the lower part.

grees.* Thus it will appear from inſpection alone, whether the needles be electrified or not, as alſo whether they be ſtrongly or weakly electrified; and the particular kind of electricity may be aſcertained, by approaching them with either a poſitive, or a negative power, which will put them in motion, and they will be found to recede from the ſame power, and to approach to the contrary power, in every direction, in which the circumſtances of the couſtruction will admit of their being moved.

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* The following methods of meaſuring the angle which the needles make when they are electrified, may be of ſome uſe, notwithſtanding they are not exact. Deſcribe a ſemicircle on a card with a radius equal to half the length of the needle. Let this ſemicircle de graduated, and, by another piece of card paſted on the back part of it, be made capable of ſliding ſteadily on a ſmall rod of wood, fixed perpendicularly in a proper ſtand, in the manner of a fire-ſcreen. Place the card at the diſtance of two or three inches from the electrified needles, and parallel to the plane in which the needles open. The axis of the needles and the centre of the ſemicircle muſt be at the ſame diſtance from the table. The eye of the obſerver being then ſo placed as to cover the centre of the ſemicircle with the axis of the needles, may obſerve the angle as meaſured by the graduation. Another method is to project the ſhadow of the electrified needles on the graduation, by placing a lighted candle at the diſtance of two or three feet from the needles, which will enable ſeveral perſons to obſerve the meaſure of the angle at the ſame time.

EXPERIMENT VII.

Sect. 23. Let a well excited electric of either kind be brought towards one extremity of the axis, and held parallel to the frame, at the diſtance of one inch and half. Let the inſulation be interrupted for a moment, by touching the communicating wire, or any part of the frame, with a finger. Then withdraw the excited electric, and the needles will be ſtrongly electrified, with a contrary power to that which was employed in the experiment.

Sect. 24. This contrary power is produced by the influence of the excited body, in the ſame manner as was before mentioned in the third experiment. Sect. 9, 10. If a poſitive power be uſed, part of the electric fluid belonging to the needles will paſs away from them at the momentary interruption of the inſulation, and then they will be negatively electrified. If a negative power be uſed, ſome electric matter will be added to them from the common ſtock, at the time of interrupting the inſulation, and then the needles will be poſitively electrified.

Sect. 25. This effect may be repeated a great many times with only once exciting the electric body; and if a ſtick of ſealing-wax be uſed, no perſon, it is apprehended, will have patience enough to determine experimentally, how often it may be repeated, which has been frequently attempted in vain, and once the needles were made to ſeparate to a right angle, or more, eight hundred times over, and there appeared to be ſtill power enough left to have continued the experiment, when it was unavoidably interrupted. This experiment cannot be carried to ſuch a length with glaſs, as with ſealing wax, becauſe it is not capable of retaining its power long enough. In a moderate dry ſtate of the air, a ſmall ſtick of ſealing wax being excited, and placed perpendicularly in a ſtand, at a proper diſtance from all other bodies, was found to retain ſome of its power thirty-ſix hours; whereas a ſolid piece of glaſs, of the ſame dimenſions, being well excited at the ſame time, and placed in the ſame circumſtances, loſt all its electricity within twenty minutes. This ſeems to be owing to glaſs more readily attracting moiſture from the atmoſphere than ſealing wax.

Sect. 26. The power of the excited electric will gradually grow weaker, whether it be applied to any uſe or not. Therefore, when this happens, it muſt be brought nearer to the frame, taking care at the ſame time not to bring it within the communicating diſtance, which would prevent the long continuation of the experiment, mentioned in the preceding ſection.

Sect. 27. Notwithſtanding one ſingle excitation of an electric body may be ſo managed, as to produce the contrary power a great number of times, yet it will not be ſufficient to give its own proper electricity to the needles, ſo as to make them ſeparate to a right angle, more than five or ſix times. The reaſon of this is obvious; for, when the excited electric has communicated to the needles ſome of its own power, it muſt have been weakened by that communication. This effect muſt be produced, by ſome of the electric fluid paſſing from the excited body to the needles, if a poſitive power be uſed; or from the needles to the excited body, if a negative power be uſed. In either caſe ſomething has been really done towards reſtoring the equilibrium, and by repeating it, the excited body muſt loſe ſome of its power every time, and after five or ſix repetitions, it will be ſo far reduced, as not to be capable of making the needles ſeparate to a right angle. Whereas in the method of procuring a contrary power, there was only an effort made to reſtore the equilibrium, which was prevented from taking place, by the reſiſtance of the intermediate air. No actual communication between the excited electric and the needles could happen, becauſe they were not brought ſo near together, as to be within the communicating diſtance, and therefore the excited body may be employed to produce the contrary electricity, as long as it may be capable of retaining the power given to it by friction.

EXPERIMENT VIII.

Sect. 28. A pair of theſe needles may be uſed as a kind of hygrometer, by giving them the greateſt degree either of poſitive or negative electricity, and then obſerving, how long they may be capable of retaining any part of the communicated power; and as that time ſhall be longer or ſhorter, we may conclude that the air is more or leſs dry: for, in a dry ſtate of the atmoſphere theſe needles have been obſerved to retain ſome of the electricity communicated to them for ſeventeen hours, but in a moiſt air they will frequently loſe the whole of their power within a few minutes, and if it be very moiſt, ſometimes within a few ſeconds. When they retain the power well, it will be only neceſſary to notice the time which paſſes, from their firſt being fully electrified till they form a right angle, becauſe it appears from a number of obſervations, made in different ſtates of the atmoſphere, that this time, be it longer or ſhorter, is generally about one fifth part of the whole time, which the needles are capable of retaining any part of the communicated electricity. The greateſt degree of dryneſs and of moiſture may be readily determined by the following obſervations. Glaſs not aſſiſted by heat will ſoon attract ſo much moiſture from the atmoſphere, even in moderate damp weather, that on touching the frame of an electrified pair of needles with it, their whole power will be deſtroyed almoſt as ſuddenly, as if the frame had been touched with a piece of wire. Therefore, when glaſs is found to inſulate well, without wiping or warming it, the air muſt certainly be in a very dry ſtate. Electric bodies of the reſinous kind are not ſo readily affected by the moiſture of the atmoſphere, as glaſs is; but theſe alſo are found to have their inſulating quality much impaired in very damp weather. Therefore, when amber will not inſulate at all, or very imperfectly, without being wiped or warmed, eſpecially if after it has been made quite dry, it ſhould ſoon return again into the ſame defective inſulating ſtate, we may then conclude that the air is much loaded with humidity.

Sect. 29. It has been juſt before obſerved, that all inſulating ſubſtances acquire dampneſs from the atmoſphere in very moiſt weather, and therefore, when that is the caſe, it is neceſſary to dry them, in order to exhibit the effects of electricity: and as this will always ſucceed for a ſhort time, it follows, that moiſture diſperſed in the atmoſphere is not ſo unfavourable to electricity, as when it is collected on the ſurface of the inſulating bodies: and from hence it appears, that air even in moiſt weather, is a more perfect electric, or has leſs of the conducting quality, than any other ſubſtance we are acquainted with at preſent.

EXPERIMENT IX.

Sect. 30. Let two pair of inſulated needles, in their natural ſtate, be ſo placed that the communicating wires may touch, and that the needles may open in planes parallel to each other, when they ſhall be electrified. Care muſt be taken, not to interrupt the inſulation, during the whole experiment. Let an excited electric be then brought towards one ſide of the frame of either pair of the needles, and held parallel to it, as near as poſſible without bringing it within the communicating diſtance. While it is in this ſituation, let the other pair of needles be withdrawn, ſo that the communicating wires may not be within half an inch of each other. Then remove the excited electric, and both pair of needles will be equally electrified, but with contrary electricities. The needles which were the fartheſt from the excited electric during its influence, will have the ſame electricity, and thoſe which were the neareſt will have a contrary power; and therefore, the electricity of the two pair being not only oppoſite in quantity, but alſo equal in degree, on holding an excited electric over the communicating wires, one pair of needles will be attracted, and the other repelled, at the ſame time; and on bringing the communicating wires again into contact, they will deſtroy each other's power, and both pair return immediately to their natural ſtate.

When two pair of needles are uſed, in order to explain the effect produced without confuſion, it may be convenient to call that pair the firſt which is neareſt to the excited body, and the other the ſecond.

Sect. 31. In this experiment, the power produced in the firſt pair of needles neceſſarily produces the contrary power in the ſecond pair, by the mediation of the communicating wires.—When the influence of a poſitive power is employed, it cauſes a part of the electric fluid naturally belonging to the firſt pair, to paſs over to the ſecond, along the communicating wires. Therefore, the ſecond pair of needles, by receiving an addition to their natural quantity, are poſitively electrified; and the firſt pair by loſing ſome of their natural quantity, are negatively electrified. If the influence of a negative power be uſed, ſome part of the natural quantity belonging to the ſecond pair, will paſs to the firſt pair, by the ſame conveyance; and therefore the firſt pair of needles will then be electrified poſitively, and the ſecond pair negatively. In both caſes, the unequal diſtribution of the electric matter, occaſioned by the influence of the excited body, is rendered permanent, by ſeparating one pair from the other, during the action of that influence.

Sect. 32. Neither pair of needles will thus acquire more than half the degree of electricity they are capable of retaining; but they may be fully electrified, by approaching one of the frames with a poſitive power, and the other with a negative power at the ſame time; and proceeding with both, in the ſame manner as was before directed when one power only was uſed: and then the greateſt degree of poſitive and negative electricity, which they are able to contain, may be produced at the ſame time in theſe two pair of needles.

Sect. 33. The quantity of the electric fluid contained in both pair of needles, is preciſely the ſame during the whole experiment, namely, their natural quantity. For, as the inſulation has been at no time interrupted; and as the excited bodies were not brought within the communicating diſtance, no electric matter can either be added to the needles, or taken from them. Their natural quantity is indeed unequally divided; but as one pair receives what the other pair loſes, and no more, they muſt be equally electrified with contrary electricities, notwithſtanding the abſolute quantity of the electric fluid in both pair is always the ſame.

EXPERIMENT X.

Sect. 34. Communicate to a pair of inſulated vertical needles, the greateſt degree of either poſitive or negative electricity, which they are capable of retaining. Bring the communicating wire of theſe electrified needles into contact with the communicating wire of another equal pair of inſulated needles of the ſame kind, but in their natural ſtate, and the power will be thus equally divided beween the two pair. Let a well-excited electric, having the ſame power as the needles, be gradually brought towards either pair, and held parallel to one ſide of the frame, and as near to it as poſſible without being within the communicating diſtance. The ſecond pair of needles will gradually ſeparate more and more from each other, and when they form the greateſt angle, let the two pair of needles be ſeparated, and then on removing the excited body, the firſt pair of needles will be in their natural ſtate, and the ſecond pair will poſſeſs the whole of the communicated electricity. Or, if a well-excited electric, having a power contrary to the power of the needles, be uſed in the ſame manner, then will the ſecond pair of needles gradually approach each other, and when they form the leaſt angle, or are nearly brought within the groove, if one pair be ſeparated from the other, and then the excited body be removed; the ſecond pair of needles will be in their natural ſtate, and the firſt pair will have acquired the whole of the communicated electricity.

Sect. 35. The different effects produced in this experiment may be explained in the following manner.

When the greateſt poſitive power is given to a pair of needles, and equally divided between theſe and another equal pair, each pair muſt have received an addition of half that quantity of electric matter, which they are capable of receiving more than their natural ſhare; and this addition is ſhifted from the firſt to the ſecond pair by the influence of a poſitive power; or from the ſecond to the firſt by the influence of a negative power. The needles which loſe as much, as was before added to them, will therefore be reduced to their natural ſtate; and the needles which receive another equal additional quantity will be fully electrified poſitively.

When the greateſt negative power is given to a pair of needles, and then equally divided between theſe and another equal pair; each pair muſt have loſt half of the quantity of electric matter, which they are capable of loſing; the other half however ſtill remains in each pair, and this remainder is ſhifted from the firſt to the ſecond pair, by the influence of a poſitive power; or from the ſecond to the firſt, by the influence of a negative power. The needles which receive as much of the electric matter, as was before taken from them, will therefore be brought into their natural ſtate; and the needles from which the remaining half is taken will be fully electrified negatively.

EXPERIMENT XI.

Sect. 36. Let a pair of inſulated needles be fully electrified either poſitively or negatively, and, care being taken not to interrupt the inſulation, let a well excited electric, having the ſame power as the needles, be placed parallel to one ſide of the frame, in different parts of the ſphere of influence, and the power of the needles will thus be weakened, more or leſs, as they may be in a nearer or more diſtant part of the ſphere of influence. If the excited body be held as near as poſſible to the frame, without being within the communicating diſtance, the needles will then loſe the whole of the communicated electricity. In moderately dry weather, all their power may be thus deſtroyed in a ſingle ſecond; but in a very dry ſtate of the air, this effect cannot be produced in leſs than three or four ſeconds. If the action of the excited body be continued a longer time, than may be neceſſary to deſtroy the communicated power, the needles will then acquire a contrary electricity, which will be weak in a dry ſtate of the air, but ſtronger when it is inclined to moiſture.*

Sect. 37. By performing this experiment with two excited electrics of the ſame kind, placed parallel to the ſides of the frame, the power of the needles may be deſtroyed at a greater diſtance, or in a ſhorter time: and in the latter part of the experiment, the greateſt degree of the contrary power may thus be given to the needles, without interrupting the inſulation.

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[*] A ſmall ring or ball, made of any conducting ſubſtance, and ſuſpended by a ſilk ſtring, may alſo be brought into a ſtate of contrary electricity, by holding an excited electric below it, about half a minute, and without interrupting the inſulation.

Sect. 38. Thus it appears, that the action of an excited body has a tendency to weaken the ſame power in the whole ſphere of influence: and this effect is perfectly conſiſtent with what was ſhewn before, in the third experiment, that an excited body produced a contrary power within the ſame limits; becauſe deſtroying one power, and producing an equal degree of the contrary power is, in fact, one and the ſame thing: and therefore it appears from the latter part of the preſent experiment, that a continuation of the ſame influence, after it has deſtroyed one power, produces the other. In the third experiment, the inſulation was interrupted, and a ready communication formed with the common ſtock; but in the preſent experiment the inſulation has not been interrupted, and therefore, when it is performed with a poſitive power, the effect produced muſt be aſcribed to the electric fluid paſſing from the needles, either immediately to the air, or over the inſulating ſubſtance to the table. When a negative power is uſed, the electric fluid muſt have the ſame conveyance, but in a quite contrary direction. From hence it follows, that electric bodies are conductors of electricity in a ſmall degree: but this will be the ſubject more immediately under conſideration in the ſecond part.

The Conſtruction of an horizontal Needle, in which the Powers of Electricity and Magnetiſm are united.

Sect. 39. Make a ſmall ivory cap in the ſhape of an acorn, and having two holes drilled into the thickeſt part of the ſide, directly oppoſite each other: in theſe the arms of the needle are to be faſtened. Let one arm be a hardened ſteel wire, the twenty-fourth part of an inch in diameter, and one inch long. Let the other arm be a ſmall ivory rod, of the ſame diameter, and of a ſufficient length to balance the ſteel wire. The whole of this needle will be about four inches long.—Let a rod of ivory, the twelfth part of an inch in diameter, and of the ſame length as the needle, be faſtened horizontally to the ſupporter, about a quarter of an inch below the point. The ſupporter ſhould not be more than one inch long, and muſt be well inſulated. Communicate a magnetic power to the ſteel wire, and let the ſouth pole, or that end which turns to the north, form the extremity of the needle. This power will be ſufficient to give the whole needle a magnetic direction, when it ſhall not be electrified, and the horizontal rod muſt be brought into the ſame direction: but as the needle will be apt to vibrate from one ſide of the magnetic meridan to the other, to prevent this, make a ſmall ſcroll of ivory, concave on one ſide and convex, on the other. Let this ſcroll be ſo faſtened to the horizontal rod, at the diſtance of half an inch from the ſupporter, that it may be turned round a little, and yet remain ſteady in any poſition; and if the ſhort arm of the needle be made to reſt againſt the concave ſide of the ſcroll, it will then not only prevent the vibrations above mentioned, but alſo confine the motion of either arm to the proper ſide, when the needle ſhall be electrified. See figure 13. The magnetic power gives its own peculiar direction to the needle, when it is not electrified; and the fixed horizontal rod, whether the conſtruction be electrified or not, preſerves that direction. The power of electricity cauſes the needle to ſeparate from the rod; and the angle of ſeparation increaſes with the degree of the communicated power.

The angle of ſeparation may be meaſured in the following manner. Deſcribe the arch of a circle of one hundred degrees on any convenient ſubſtance, with a radius a little ſhorter than the length of the ivory arm. Let this arch be graduated, and ſo placed on the table, that the centre of the graduation may be under the middle of the ſtand, and the firſt degree under the ivory arm. When the conſtruction is electrified, the eye of the obſerver being then placed above, ſo as to cover the middle of the ſupporter with the ivory arm, and kept ſteady in the ſame plane, which will be that of the needle and its ſupporter, may eaſily obſerve the angle of ſeparation. This angle may be alſo meaſured, by placing a lighted candle on a ſtand, pretty high above the level of the needle, and on the ſame ſide of the rod as the ſhorteſt arm; and when the ſhadow of this arm ſhall be brought to reſt on the middle of the ſupporter; then will the middle of the flame of the candle be in the ſame plane as the needle and the ſupporter; and the ſhadow of the longeſt arm will conſequently ſhow what part of the graduation ſhall be interſected by the common plane of the needle and its ſupporter, and thus meaſure the angle of ſeparation. But the moſt exact method of meaſuring this angle will be, to place the conſtruction, together with the graduation, on the face of a looking glaſs; and after every part has been properly adjuſted and electrified, the eye being then placed above ſo as to make the ivory arm coincide with its own reflected image in the glaſs, may eaſily obſerve, at what particular degree this coincidence ſhall happen, which will be the meaſure of the angle required.

Sect. 40. This needle will be convenient for ſhowing the influential electricity, by holding the excited body parallel to the under ſide of the horizontal rod, while the inſulation is interrupted:

rupted: and, as it is not only capable of ſhewing a very ſmall degree of power; but is alſo more ſteady than the other horizontal needles; therefore it may be uſed to advantage in ſeveral of the preceding experiments, and will even ſupply the want of a pair of vertical needles, in many caſes.

Sect. 41. The uſe of this conſtruction appears to be confined to the magnetic meridian; but it may be uſed in any other direction, by placing a good artificial magnet in that direction, and with its friendly pole ſo near to the ſteel extremity of the needle, that the attraction between them may be a little more than ſufficient to counteract the magnetiſm of the earth. A good magnetic bar, three inches three quarters long, and the ſixth part of an inch ſquare, placed horizontally on a ſtand, will be ſufficient to anſwer this purpoſe, at the diſtance of four inches. It muſt be obſerved, however, that the magnetic meridian is the beſt ſituation for uſing this conſtruction: becauſe, if it be employed in any other, it will be neceſſary to take into the account the magnetiſm of the earth, which muſt either increaſe or diminiſh the angle of ſeparation, in every other poſition.

Sect. 42. This conſtruction has been ſometimes uſed as an electrometer; and perhaps a better inſtrument of this kind might be conſtructed on the ſame principle, by making a few alterations, and by employing a good artificial magnet at the ſame time: this however muſt depend on the iſſue of ſome experiments, which have not hitherto been ſufficiently tried.

Sect. 43. Electricity and magnetiſm are here united in the ſame needle, and made to counteract each other; and as this combination does not appear to produce the leaſt effect in deſtroying or increaſing either of theſe powers; it is therefore probable, there is little or no relation between them: but this will be more particularly conſidered, in another place. See §. 103.

Sect. 44. Excite a ſmall electric of either kind, and bring every part of its ſurface into contact with any conducting ſubſtance, until it can no longer communicate its own proper electricity. Bring this electric ſideways towards the extremity of an inſulated needle in its natural ſtate, and it will attract that needle, though it be no longer capable of communicating the leaſt power. Bring it towards a needle having the ſame electricity, and it will repel it. Laſtly, hold it under the greateſt part of the horizontal rod, either very near or in contact with it, and on touching any part of the conſtruction with a conductor not inſulated, and then removing the electric body, a ſmall degree of the contrary power will be produced, ſo as to make the needle ſeparate to an angle of thirty degrees. This effect may be repeated ſeveral times; and from hence, therefore, it appears, that an excited electric, after its power has been ſo far reduced, as to render it incapable of communicating its own proper electricity, does however ſtill retain a permanent degree of the ſame power, by which it can produce a ſmall degree of influential electricity, in a body in contact with it.

ELECTRICAL EXPERIMENTS,

AND

OBSERVATIONS.

PART II.

IT has hitherto been principally conſidered, what ſome of the effects are, which an electric power is capable of producing on conducting ſubſtances; and it will be now proper alſo to attend to thoſe effects, which may be produced by the ſame power on electric bodies themſelves.

EXPERIMENT XII.

Sect. 45. Let a piece of good ſilk riband, or woollen cloth, about one inch wide and four inches long, be placed on the table; and on rubbing the whole of the upper ſide with a ſtick of ſealing-wax, or with glaſs, in its natural ſtate, the riband or cloth, and the rubbing part of the electric body will thus acquire contrary electricities, as will appear on bringing both towards needles differently electrified. The riband or cloth will thus get a ſufficient degree of power to electrify a pair of vertical needles. It appears alſo to act in the ſame manner on both ſides, though one ſide only was rubbed; and will retain ſome part of the power ſeveral minutes, though it be allowed to remain on the table, without the leaſt care. Thus it appears, that the excited electric and the rubber have contrary powers.

The Conſtruction of Horizontal Needles made of various Electric Subſtances.

Sect. 46. A needle may be made of amber, tortoiſeſhell, Indian graſs, or ſilk.

I. Of Amber.—Let a piece of amber, two or three inches long, be made into a needle, as nearly reſembling the ſhape of the ivory horizontal needle before mentioned, as the brittle nature of this ſubſtance will admit of; or, a piece of amber of the ſame length, and about the tenth part of an inch thick, may be filed into a ſerpentine form as in figure 6: or any oblong piece of amber will anſwer the purpoſe, if it be made to turn freely on a pointed ſupporter. Let the needle be well poliſhed.

II. It may be made of tortoiſeſhell, which may be eaſily formed into as ſlender a needle as ivory itſelf, and is alſo capable of receiving a good poliſh.

III. Indian graſs is nearly as good an electric ſubſtance as tortoiſeſhell. It is ſaid to be a vegetable production, brought from Italy in the form of long ſtrings, and is frequently uſed by the angler, on account of its ſtrength and tranſparency, for the loweſt part of his line, to which the hook is faſtened. Two pieces of this ſubſtance, about one inch and a half long, being connected with an ivory cap, will make a needle, which is well adapted to the preſent purpoſe.

IV. A needle may be made of ſilk in the following manner. Form a ſkein of ſilk from the worm, of about forty or fifty rounds, and long enough to admit of two knots being tied over the whole ſkein, near the middle, and juſt far enough aſunder, that a proper cap may paſs between them. Let a cap be made of ivory, having a ſmall bead quite round the lower part, Paſs the cap through the middle of the ſilk fibres, and between the two knots, The bead at the bottom of the cap will prevent the ſilk from ſlipping downward, and a ring of ivory being well fitted to the upper part of the cap will prevent it from ſlipping upward. Let then the ends of the ſkein be cut open, and the fibres left about an inch long, on both ſides of the cap.

EXPERIMENT XIII.

Sect. 47. Let a ſmall ivory rod, three inches long, and having a ball of ivory fixed on one of its ends, be faſtened by the other end to the ſupporter, about half an inch below the point. After mounting one of the needles, juſt before deſcribed, on the ſupporter, apply an excited electric of either kind to the ball, and the ſame power will be gradually communicated to the whole needle, as will appear by approaching it with a power of the ſame kind, at ſeveral ſucceeding ſhort intervals, during the experiment. The amber needle will not get all the electricity which it can thus receive, without repeating the application of the excited electric ſeveral times, and then, it will be attracted or repelled, in the ſame manner, and at the ſame diſtance as an electrified needle of ivory, of the ſame weight and length. If a needle of the fourth ſort be uſed, the gradual communication of the power will be rendered viſible, by a ſlow ſeparation of the ſilk fibres; and when it is fully electrified, theſe fibres will recede ſo far from each other, as to form a kind of half globe on each ſide of the cap, reſembling the down of a thiſtle. Theſe needles being made of electric ſubſtances, which are the moſt imperfect conductors, muſt therefore receive, or part with, the electric fluid the more ſlowly: and conſequently, will require ſome time to receive either a poſitive, or a negative power; and when they are electrified, they will, for the ſame reaſon, continue in that ſtate much longer than thoſe which are made of better conductors.

The ſilk needle is ſhewn in its natural ſtate, and fully electrified in the ninth and tenth figures.*

Sect. 48. In the laſt experiment, the ſame power muſt be communicated to the inſulating amber as to the needle; and this will appear to be the caſe, by examining the upper part of the amber, after the needle and its ſupporter have been removed. A proper application of the influence of the ſame excited electric, when it is in full force, will be ſufficient to deſtroy this power of the inſulating body, and the continuation of the ſame influence will alſo produce a contrary power in the upper part of the amber. The diſtance at which the excited electric muſt be held, and alſo the length of time it ſhould be held there in order to produce theſe effects, muſt be varied, as the atmoſphere may be more or leſs diſpoſed to dryneſs, or to moiſture.

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* This needle made of ſilk, being well electrified will be found to have a ſufficient degree of power, to bring a pair of vertical needles into a ſtate of contrary electricity, ſeveral times over, by employing it inſtead of the excited electric, as in the ſeventh experiment.

EXPERIMENT XIV.

Sect. 49. When the atmoſphere is in that ſtate which is the moſt favourable for electrical experiments, mount an amber needle on a ſupporter made of ſome electric ſubſtance, and having a pointed wire fixed in its upper extremity, juſt long enough to admit the needle to move freely on it. Let the electric body be frequently excited in the courſe of this experiment, that it may be always uſed when it is in full force.

I. Approach the needle in its natural ſtate with an excited electric, and it will be attracted; but at a much leſs diſtance than a needle made of ivory of the ſame length. While the end is thus attracted, it will be repelled by a contrary power, and alſo by any conducting body not inſulated, brought towards it.

II. Keep the ſame end of the needle in a ſtate of attraction for a few ſeconds, and it will then be capable of being attracted at a greater diſtance than it was at firſt.

III. Bring the excited electric to the diſtance of the eighth part of an inch from the ſame end of the needle, and after keeping it there about half a minute, let it be removed, and the ends of the needle will then have acquired different electricities, the attracted end being always of a contrary nature to the power employed.

IV. Bring the excited electric to about the tenth or twelfth of an inch, or ſtill nearer, and on repeating this ſeveral times, with the excited electric in full force, the attracted end of the needle will at laſt acquire the ſame electricity as the power employed, and will then be repelled by it.*

Sect. 50. In a damp ſtate of the air, the amber needle and the ſupporter ſhould be well dried by the fire, and if the experiment be then performed in the ſunſhine, this or any other moderate degree of heat will be generally found ſufficient to prevent any of the moiſture of the atmoſphere from collecting on the ſurface of the amber during the whole experiment.

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* It is proper to obſerve, that after frequently repeating the laſt part of this experiment with the greateſt care, it ſtill remained doubtful whether an electric power could be communicated to the amber needle, immediately from theſe ſmall electric bodies, even through the leaſt portion of air; for it was often found neceſſary, to bring the excited electric into contact with the end of the needle, and, in a very dry ſtate of the air to repeat it, before this event could be obſerved; and when it happened at a little diſtance, a very ſmall thread was often obſerved between the excited electric and the needle, which might give a paſſage to the electric fluid, and which it was ſuppoſed the excited body either carried with it from the rubber, or attracted from the atoms floating in the air: but, as a communication ſometimes appeared to take place, at a little diſtance, when no ſuch thing was noticed, it is therefore thus ſtated as in the fourth particular.

Sect. 51. On comparing the laſt experiment with the fourth, it appears, that the ſame effects are gradually produced in the amber needle, which were obſerved before to take place immediately in the ivory needle; namely, the different ends have acquired contrary electricities from the influence of the excited body, which in the preſent caſe ſlowly ſhifts a part of the electric fluid, naturally belonging to the amber needle, from one end of it to the other; and theſe effects muſt not only be produced by degrees, but will alſo continue for ſome time after the excited electric has been removed, and for the ſame reaſon, becauſe amber is one of the moſt imperfect conductors. When this experiment is performed with a tortoiſeſhell needle, all the ſame effects will happen in a ſhorter time, and at a greater diſtance, than with a needle made of amber, but will not be ſo laſting, becauſe tortoiſeſhell is a better conductor than amber.

Sect. 52. It appears from the third particular of the laſt experiment, that air is a more imperfect conductor of the electric fluid than amber. For, if the conducting quality in both were equal, as the air muſt be allowed to be in contact with the whole ſurface of the amber needle, the electric matter would, in that caſe, find a more ready paſſage between the attracted end of the needle and the air, than between one end of the needle and the other, and conſequently the remote end of the needle could not be brought into the ſame ſtate of electricity as the power employed.

The effects of the contrary electricities, produced at the ſame time, in the different ends of the needle, by the influence of an excited electric, may be rendered viſible in the firſt inſtance, by the two following experiments.

EXPERIMENT XV.

Sect. 53. Let a compound horizontal needle of the firſt ſort, § 13, be made of tortoiſeſhell, and mounted on an electric ſupporter, as in the laſt experiment. It will be convenient, for the preſent purpoſe, to make both the needles of nearly the ſame length, and therefore the lower needle muſt be conſiderably thicker than the other, that it may be heavy enough to keep the centre of gravity of the whole com-

pound

pound needle lower than the point on which the principal needle moves. It will be alſo proper to give different forms to the extremities of the index, as well as of the principal needle, in order to diſtinguiſh one end from the other. Bring an excited electric ſo near, as to attract one end of both needles at the ſame time, and after keeping it at the diſtance of half an inch from each, about four or five ſeconds, let it be removed, and it will immediately appear from the motion of the needles, that the different ends of both have acquired contrary electricities; for, the ends which were the neareſt together, during the influence of the electric body, will not only recede from each other, but will alſo evidently attract, and be attracted by, the oppoſite ends of the other needle, and after making ſeveral vibrations, in which they will paſs each other, the two needles will at laſt ſettle lengthwiſe, one over the other, ſo that the two extremities which were at firſt attracted by the excited electric, and were conſequently then on the ſame ſide, will now be on contrary ſides. Both needles will move in order to take this ſituation, but the greateſt part of the motion muſt be performed by the upper needle, becauſe it is the lighteſt.

EXPERIMENT XVI.

Sect. 54. The ſame thing may be ſhewn in a different manner, by bringing an excited electric to the diſtance of half an inch from one extremity of the ſilk needle, mounted on an electric ſupporter, and the fibres of the other end will gradually ſeparate from each other. Keep the excited body in the ſame ſituation for a few ſeconds, and, on withdrawing it, a number of fibres from both ends of the needle will fly towards each other, and come into contact, which is a neceſſary conſequence of the flexibility of the fibres, and of the different ends of the needle having acquired contrary electricities.

EXPERIMENT XVII.

Sect. 55. Let a pair of vertical ivory needles mounted in a proper frame, be inſulated and well electrified, either poſitively or negatively. Place another inſulated pair of the ſame ſort, but in their natural ſtate, at the diſtance of eight or nine inches from the former, and in ſuch a poſition, that theſe needles when they open, and the frame of the firſt pair may be in the ſame plane. Let an electric body of the contrary kind be well excited, and the whole of its power applied to the ſecond pair, by drawing it along between the needles, parallel to the axis, and on that ſide of the frame which is the fartheſt from the firſt pair: and the ſecond pair of needles will not only receive the power thus applied to them, but, the firſt pair will at the ſame time loſe the whole of their power, as will appear by the needles coming ſuddenly together within the groove.

Sect. 56. It appears from this experiment, that a ſingle application of one of theſe ſmall excited electrics, to the ſecond pair of needles, is not only capable of electrifying them, but alſo of producing a momentary electricity of the ſame kind, in the intermediate air, ſufficient to deſtroy the contrary power of the firſt pair of needles, at the diſtance of nine inches. It muſt not, however, be ſuppoſed that the ſame electric matter paſſes the whole way through the air, from one pair of needles to the other; but, that the electric matter naturally belonging to the intermediate air is put in motion, and only ſhifted onward a little, towards either one pair of needles or the other, as a poſitive or a negative power may be applied to the ſecond pair.

Sect. 57. If the experiment be made in many other relative poſitions of the two pair of needles, beſides thoſe which are included in the terms of the experiment, the electricity of the firſt pair may be ſenſibly diminiſhed, and, when the two pair are brought nearer, may alſo be deſtroyed. From hence it appears, that the effect produced by the mediation of the ſecond pair, is not confined to the plane in which theſe needles open, notwithſtanding the effect is ſtrongeſt, and therefore will extend to the greateſt diſtance in that direction.

Sect. 58. If the excited electric be applied to the ſecond pair of needles, on that ſide of the frame which is the neareſt to the firſt pair; then the contrary power of the firſt will be only weakened by a ſingle application, and it cannot be wholly deſtroyed by ferquently repeating it, notwithſtanding the electric body be well excited immediately before each application. From hence it appears, that the principal effect on the air, in this experiment, muſt be produced by the oppoſite extremities of the needles, and not by thoſe between which the excited electric was applied.

Sect. 59. It has been obſerved before, that one of theſe ſmall electric bodies, if it be well excited, was capable of communicating its own proper electricity to a pair of vertical needles, ſo as to make them ſeparate to a right angle five or ſix times. § 27. Therefore it is the exceſs of the power beyond what the ſecond pair of needles are capable of retaining, which principally acts on the air in the preſent caſe, and this experiment will ſucceed at double the diſtance before mentioned, or farther, provided the electric body be frequently excited and applied, as in the experiment by which the contrary power of the firſt pair of needles will be gradually diminiſhed, and at length deſtroyed.

Sect. 60. Thus then it appears, from the five laſt experiments, that electric bodies themſelves are conductors in a certain degree, even when ſmall electrics are employed: and if the electrician will attend to this circumſtance, when he is uſing a well excited glaſs cylinder, he will find, that a conſiderable quantity of the electric fluid is conſtantly ſtealing over the ſurface of the inſulating ſubſtance.

EXPERIMENT XVIII.

Sect. 61. Form a kind of cubical lanthorn of plates of crown window glaſs, ſix inches ſquare, united in any frame. Let the whole of one of the ſide plates be covered over with a coating of ſealing wax, or of copal varniſh, which will render it fit for uſe in almoſt every ſtate of the atmoſphere. Then let the third and ſeventh experiments be repeated, by placing the proper needles in this cavity, and bringing the electric power towards the outſide of the varniſhed plate; and they wiil ſucceed in every part: and, in general, all thoſe effects may be produced, but in a leſs degree, which have been already ſhewn to belong to the ſphere of influence, notwithſtanding the interpoſition of the glaſs plate.

Sect. 62. This experiment has been alſo found to ſucceed through the ſide of a dome-ſhaped glaſs veſſel, the twelfth part of an inch thick, which was made for the receiver of an air pump. But the moſt eaſy manner of performing it is, to uſe a ſingle plate of glaſs, placed perpendicular on one of its edges, in any convenient ſtand: and the only reaſon for uſing the cubical lanthorn before mentioned, was to obviate the following objection. *That the influence of the excited body might poſſibly be conveyed round the edges, and not through the ſubſtance of the glaſs plate.* But if it be conſidered that the influence of electricity acts in ſtrait lines, in all directions; and that no experimental proof can be given of its thus paſſing the edges, when proper care has been taken to keep always ſome part of the glaſs plate directly between the whole of the excited body and the needles, this objection muſt appear to have no weight, and therefore the experiment may be performed ſimply with a glaſs plate.

Sect. 63. The influence of one of theſe ſmall excited electrics has been alſo obſerved to act through a piece of thick plate glaſs, by repelling needles which had the ſame power, and by attracting thoſe that had a contrary power, when the excited body and the needles were kept on different ſides of the plate.

Sect. 64. It muſt not, however, be conluded, that glaſs is permeable by the electric fluid; or in other words, that the ſame electric matter is capable of paſſing from one ſurface of the plate to the other, through the pores of the glaſs. Becauſe, if this really happened, it is apprehended that a glaſs plate could never be charged. When a conſiderable quantity of this fluid is collected, in charging a thin glaſs phial, it will ſometimes make a breach through the ſubſtance of the glaſs for its paſſage: and, it is evident from this ſingle fact, that the electric matter could not paſs through the glaſs, before it had acquired ſo much power by the accumulation, as to render it capable of deſtroying the texture of the glaſs itſelf. Here it may be juſt obſerved, that the air on the outſide of the exhauſted receiver of an air pump cannot paſs through glaſs, notwithſtanding it is aſſiſted by the great preſſure of the incumbent atmoſphere, and yet ſound, which is nothing more than vibrations communicated to the air, is capable of paſſing through glaſs, ſo that the ear can diſtinguiſh all its different modifications.

Sect. 65. It appears from the laſt experiment, that the influence of an electric power acts thro' glaſs, in the ſame manner as it does through the air. It might reaſonably be expected that ſo denſe a body as a glaſs would not tranſmit this influence without ſome diminution, eſpecially when ſuch ſmall electric bodies are employed as in the preſent caſe. It will appear alſo, from the following experiment, that the influence of an electric power produces a permanent contrary electricity in the glaſs plate, and therefore ſome part of the influence is likely to be ſuſpended by this operation on the glaſs itſelf.

EXPERIMENT XIX.

Sect. 66. Let an excited electric of either kind be brought within half an inch of one ſide of the plate of window glaſs before mentioned, and held parallel to the middle of it for a few ſeconds; and then on withdrawing the excited body, and bringing an electrified ivory horizontal needle towards the middle of either ſide of the plate, if the needle has the ſame electricity as the power employed, the glaſs will attract it; or if it has a contrary electricity the glaſs will repel it.

Sect. 67. It appears, therefore, that the ſurface of the glaſs plate, immediately oppoſite to the excited body, has acquired a permanent contrary electricity, from the influence of that body which cauſes a portion of the electric matter belonging to the glaſs, to ſhift from ſome parts of the ſurface to others. Notwithſtanding the electric power of the glaſs plate thus produced, muſt reſide principally about the middle of that ſide, which was more immediately expoſed to the influence of the excited body, yet the electrified needle will be attracted, or repelled, on both ſides of the plate, becauſe the influence of electricity appears by the preceeding experiment, to act in the ſame manner through glaſs as it does through the air.

EXPERIMENT XX.

Sect. 68. When the middle of the glaſs plate has acquired a degree of permanent electricity, as in the laſt experiment, let a well excited electric, having the ſame power as the glaſs plate, be held parallel to it as before, and the power of the glaſs will not only be deſtroyed, but a contrary power will alſo be produced. This effect will require a longer or a ſhorter time according to the temperament of the atmoſphere.

Sect. 69. If the whole length of one of theſe ſmall excited electrics be brought into contact with the ſurface of the glaſs plate, the glaſs will not, by that means, acquire the ſame power as the excited electric, but a power of the contrary kind, as before mentioned, though in a leſs degree than by holding it at ſome little diſtance. The reaſon of this will appear from the following conſiderations. The electric fluid muſt always paſs with great difficulty between an excited body and any other electric ſubſtances in their natural ſtate, becauſe they are bad conductors. See § 49. Let it be conſidered alſo, that the contact between the ſide of a cylinder and a plane can be only a ſtrait line; and that the parts of the excited body on each ſide of the line of contact remaining ſtill in force, muſt by their influence produce a contrary power, and which appears to be more than ſufficient in the preſent caſe, to balance that power which the plate may get from an actual paſſage of ſome electric matter, between the excited body and the glaſs, and therefore after the contact, the glaſs plate will have a contrary power. But a method of communicating its own proper electricity to the middle of the plate, from one of theſe ſmall excited bodies, will be ſhewn in the ſecond part of the next experiment.

EXPERIMENT XXI.

Sect. 70. P. I. Let a tortoiſeſhell horizontal needle be mounted on an electric ſupporter, and placed ſo near the middle of the inſide of the glaſs plate, that it may have juſt room enough to turn round, without touching the plate. On bringing an excited electric towards the middle of the outſide of the glaſs, as in the laſt experiment, one end of the needle will be ſtrongly attracted; and after keeping it thus attracted for a few ſeconds, let the excited electric be removed, and the needle will immediately turn half round, ſo that the other end of the needle will be then attracted by the glaſs.

P. II. Let an inſulated pair of vertical needles be placed ſo near the middle of the outſide of the glaſs plate, and in ſuch a poſition, that when they are electrified, their extremities on one ſide of the frame may move towards the glaſs, and be within an inch of it. Then on electrifying theſe needles fully, by applying the ſame excited electric when it is in full force, to the outſide of the frame, the tortoiſeſhell needle will again turn half round, and that end of it which was attracted by the excited electric in the former part of the experiment, will now be attracted by the glaſs plate; and this attraction will continue after the excited electric and the electrified pair of needles have been removed.

Sect. 71. The firſt part of the experiment may be thus explained. As the influence of an excited electric acts in the ſame manner through glaſs as it does through the air, § 61, the two ends of the tortoiſeſhell needle muſt have acquired different electricities, and the attracted end of the needle have got a power contrary to that with which the experiment was made. § 49. 3. § 51. But it appears alſo from the laſt experiment, that the middle of the glaſs plate muſt alſo have acquired the ſame contrary power, from the ſame influence; and therefore on removing the excited body, the neareſt extremity of this needle will recede from the glaſs plate, becauſe they have the ſame power, and the other extremity will be attracted by the middle part of the glaſs, becauſe they have contrary powers. In the ſecond part of the experiment, the proper electricity of the excited body was communicated to the middle of the glaſs plate, by the mediation of the vertical needles, and in a ſufficient degree not only to deſtroy the influential power of the glaſs plate, acquired in the former part of the experiment, but alſo to give it a permanent electricity of the contrary kind; and becauſe the power of the middle of the plate was thus changed, therefore the needle will again turn half round, and the other end of it will now be attracted by the middle of the glaſs.

Obſervations on ſimple Electrification and the charged Phial.

Sect. 72. An electric power communicated to any inſulated conducting ſubſtance has been named ſimple electrification, in order to diſtinguiſh this particular ſtate from that of the charged phial: but it will appear whether this diſtinction ought to be retained or not, by taking a comparative view of both theſe caſes. And, if the changes which an electrical power in general is capable of making in the electrical ſtate of any ſubſtance contained within the ſphere of its influence, be taken into conſideration, and compared with thoſe which have been obſerved in the charged phial, it is apprehended that they will not appear to be different in any material circumſtance.

I. In the charged phial, when the inſide has either kind of electricity communicated to it, the outſide is found to poſſeſs a contrary power. It appears alſo from the preceding experiments, that either kind of electricity always produces the other on any conducting ſubſtance placed within the ſphere of influence. And as the ſame effect is alſo produced on electrics themſelves, in the ſame ſituation; and as ſome portion of the air, ſuppoſing no other ſubſtance to be near enough, muſt be unavoidably expoſed to ſuch influence, it neceſſarily follows, that neither power can exiſt without the other, and therefore, in every poſſible caſe, poſitive and negative electricity are inſeparably united.

II. A phial cannot be fully charged, by which the outſide acquires a contrary electricity, unleſs the external coating has a communication by ſome conductor with the earth. In the ſame manner a full charge of the contrary electricity cannot readily be procured in theſe experiments, without a ſimilar communication.

III. In both caſes the interpoſition of an electric body between the contrary powers is abſolutely neceſſary. In one caſe that body is glaſs, in the other it is air; and the experiment will not ſucceed in either, unleſs both the glaſs and the air be tolerably free from moiſture.

IV. It appears from the eighteenth experiment, that the influence of electricity acts in the ſame manner through glaſs, as it does through the air, and produces a contrary power in both caſes.

V. A communication of the electric matter is more eaſily made through the fluid yielding ſubſtance of the air than through glaſs; which is ſo hard and ſolid a body, as to require a very conſiderable degree of power to ſeparate its component particles: this however ſometimes happens, and a hole is made through the glaſs itſelf, without deſign, in attempting to charge a very thin phial as highly as poſſible, in the moſt favourable ſtate of the atmoſphere.

VI. A conducting body receives the ſtrongeſt charge of the contrary electricity, in theſe experiments, when it is brought as near as poſſible to the electric power, without being within the communicating diſtance. And it is well known that the thinneſt phial, if it be ſtrong enough to prevent a communication between the two ſurfaces, will always receive the higheſt charge.

VII. The electricity of the external ſurface of the charged phial cannot be deſtroyed, ſo long as the internal ſurface remains in force, and continues to exert its influence through the glaſs, becauſe this influence was the cauſe of the contrary electricity on the external ſurface, and muſt therefore preſerve it. In like manner, and for the ſame reaſon, when a pair of needles have been electrified by the influence of an electric power acting through the air, the electricity of theſe needles cannot be taken away without deſtroying or removing the power employed.

VIII. If part of the courſe which the electric matter takes in diſcharging a phial be through the air, a ſmall part of the charge will always remain: becauſe the whole of the redundancy on one ſurface is not capable of forcing a paſſage through the reſiſting medium of the air, in order to ſupply the deficiency on the other ſurface. But if every part of the circuit, from the internal to the external coating, conſiſts of the beſt conductors: and if the coated ſurfaces be nearly equal, and directly oppoſite to each other, the phial will then appear to have retained no part of the charge, ſo far as it is covered with tinfoil; but the parts of it above the coating on both ſides will, however, ſtill retain the contrary electricities, after the circuit has been completed.* A reſidue of the charge may alſo be obſerved in every other inſtance of electrification, in which the degree of electricity is ſufficient to force a communication between the electrified body and a conductor not inſulated, through a ſmall portion of the air: and if the

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* The whole remainder of the charged phial muſt not, however, be aſcribed to the cauſe above mentioned: for after taking away that part of it belonging to the coated ſurface, which could not force a paſſage through the air, if the phial be allowed to ſtand a ſhort time on the table, the coated ſurface will again gradually acquire ſome power, which muſt be derived from the charge of the phial above the coating. Another ſource of the reſiduum will appear in the next experiment.

experiment be carefully made, it will appear, that the whole of the redundancy is not capable of paſſing through the reſiſting intermediate air, in any caſe, and therefore a part of the charge muſt always remain. This may be conveniently ſhewn by uſing a well excited Electrophorus, of about five inches diameter, the metal cover of which may be ſo ſtrongly electrified, as to force a communication through the air, to any good conductor not inſulated, at the diſtance of three quarters of an inch. After this a ſecond communication much weaker than the firſt, may be made at the diſtance of about the twelfth part of an inch, which is the reſidue of the charge; or rather a part of it: for if the ſecond communication be carefully made through the air, without touching the cover, it will be found ſtill to have retained enough of the firſt charge to electrify a pair of vertical needles.

Sect. 73. As it appears from this view, that both theſe caſes are ſimilar, in ſo many remarkable particulars, it follows, that they are eſſentially the ſame, notwithſtanding they differ in the degree of power and ſome other circumſtances, which may alter the form of an experiment, without changing its nature. It is apprehended therefore, that the above mentioned diſtinction, § 72, will not only appear to be unneceſſary, but alſo, that either power cannot poſſibly exiſt without the other, as it has been ſhewn under the firſt particular, that poſitive and negative electricity were inſeparably united. But here it will be proper to examine more particularly the nature of charged glaſs.

Experiments and Obſervations on a charged Plate of Glaſs.

Sect. 74. When a plate of coated glaſs has been charged, and the circuit between the coatings has been completed, by the mediation of a good conducting ſubſtance, no part of the coated ſurface is ſuppoſed to retain any part of the charge; but, according to the commonly received doctrine, the whole of it is ſaid to be diſcharged; or in other words, to be brought into its natural ſtate. This however is not really the caſe, as will evidently appear from the following experiment; the deſign of which is to ſhow the effects produced, by charging and diſcharging a plate of glaſs.

EXPERIMENT XXII.

The Conſtruction.

Sect. 75. Let the middle of a piece of crown window glaſs, ſeven inches ſquare, be placed between two circular plates of braſs, about the ſixteenth part of an inch thick, and five inches in diameter. In order to enable theſe plates to retain a greater degree of power, it will be proper to terminate each of them with a round bead the third part of an inch thick; and the whole of the bead ſhould be formed on one ſide of the plate, that the other ſide may remain quite flat, and apply well to the ſurface of the glaſs. Let the whole be inſulated about four inches above the table, and in an horizontal poſition, by faſtening one end of a cylindrical piece of ſome good inſulating ſubſtance to the middle of the under plate, the other end of it being fixed in any convenient ſtand. Let a like inſulating ſtem be faſtened to the middle of the upper plate. Let a braſs chain, which may eaſily be removed, reach from the under plate to the table. In the laſt place, bend a piece of braſs wire into ſuch a ſhape that it may ſtand perpendicularly on the upper plate; and let the upper extremity of this wire be formed into an hook, that it may be removed at any time by the aſſiſtance of a ſilk ſtring, without deſtroying the inſulation of the plate.

The glaſs being thus coated with metal on both ſides, and having alſo a proper communication with the table, will admit of being charged; and both coatings may be ſeparated from the glaſs, and examined apart, without deſtroying the inſulation of either: for the upper coating may be ſeparated by the means of its own proper ſtem; and the under coating may be ſeparated by taking hold of the corners of the glaſs, and lifting the glaſs itſelf. As glaſs readily attracts moiſture from the atmoſphere, it will therefore be neceſſary to warm it in the beginning, and to repeat it ſeveral times in the courſe of the experiment, unleſs the air ſhould be very dry.

P. I. *The* CHARGE.

Excite a ſmooth glaſs tube, of the common ſize, by rubbing it with ſilk, and apply it repeatedly to the bent wire, until the glaſs be well charged. Then remove the chain, which reaches from the lower plate to the table, and alſo the charging wire from the upper plate, by laying hold of its hook with a ſilk ſtring. It neceſſarily follows, from conſidering the quality of the power employed in the preſent caſe, that the upper ſurface of the glaſs, together with the upper coating, muſt be electrified poſitively; and that the under ſurface and coating muſt be electrified negatively: but, as it is deſigned in this experiment to examine the powers of charged glaſs; that no virtue may be imputed to the glaſs but what really belongs to it, let both coatings be ſeparated from it; and after they have been brought to their natural ſtate, by touching them with a conducting body not

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inſulated, let the glaſs be replaced between them, and whatever effects may now be produced, muſt be aſcribed ſolely to the powers of the charged glaſs. On bringing a finger near the upper coating, a ſmall electrical ſpark will appear between that coating and the finger, attended with a ſnapping noiſe. Apply a finger in the ſame manner to the under coating, and the ſame thing will happen. This effect cannot be produced twice, by two ſucceeding applications to the ſame coating; but it may be repeated ſeveral hundred times over, in a favourable ſtate of the atmoſphere, by alternate applications to the two coatings; and the powers of the glaſs will be thus gradually weakened.

This part of the experiment may be explained, by obſerving, that the contrary electricities have a natural tendency to produce, and to preſerve each other, on the oppoſite ſides of a plate of glaſs; and therefore, the increaſe or decreaſe of power, on either ſurface, muſt be regulated by the increaſe or decreaſe of the contrary power on the other ſide: and as in charging a plate of glaſs poſitively, no gradual addition of electric matter can be made to the upper ſurface, without a proper conveyance for a proportionable part to paſs away from the lower ſurface; ſo in this method of uncharging it, the electric matter cannot be gradually taken away from the upper ſurface, without adding a proportionable part to the under ſurface: one operation is the reverſe of the other, and ſo are the effects: one caſe being attended with an increaſe, and the other with a decreaſe of power.

Let the glaſs be again fully charged, and after bringing both coatings to their natural ſtate as before, let the glaſs be replaced between them; and on touching the upper coating with a finger, and then ſeparating it from the upper and poſitive ſurface of the glaſs by the inſulating ſtem, this coating will acquire a weak negative power, which will be ſufficient to produce a ſmall ſpark while the glaſs is in full force, though after the power of the glaſs has been reduced, it will give little or no ſpark: but, in both caſes, on touching the coatings alternately two or three times, the negative power of this coating, when ſeparated from the poſitive ſurface of the glaſs, will be ſo conſiderably increaſed, as to produce ſtrong negative ſparks.— This effect may now be repeated ſeveral times, by only touching the upper coating, but the ſparks will grow weaker every time; and they may be reſtored again to nearly their former ſtrength, by alternate applications to both coatings, as before. The ſame things will alſo happen to the under coating, in the ſame circumſtances; but with this difference, that the power of the under coating, on being ſeparated from the under and negative ſurface of the glaſs, will be poſitive. And thus a long ſucceſſion of both poſitive and negative ſparks may be produced, in favourable weather; or at any time by keeping the glaſs moderately warm.

It appears from this part of the experiment, that each of the ſurfaces of the charged glaſs has a power of producing a contrary electricity in the coating in contact with it, by a momentary interruption of the inſulation, in the ſame manner as was ſhown before of an excited electric, in §. 44. It neceſſarily follows in producing theſe effects, that more electrical matter muſt have paſſed away from the upper coating, at the time of touching it, than the ſame coating could receive from the upper ſurface of the glaſs; and therefore, the upper coating, by loſing ſome of its natural quantity, will be negatively electrified; and alſo, that more electric matter muſt have been added to the under coating, at the time of touching it, than the under ſurface of the glaſs could receive from it; and therefore the under coating, by receiving ſome addition to its natural quantity, will be poſitively electrified. It appears further, that the greateſt degree of this influential power, which may be conſiſtent with the circumſtances of the caſe, will be produced in either coating, by taking care at the ſame time to bring the oppoſite coating into a like ſtate of influential electricity: and thus it is evident, that the influential powers of the two coatings have the ſame relation to each other, as the contrary powers of the glaſs itſelf, and will therefore always increaſe or decreaſe together.

P. II. *The Diſcharge.*

The glaſs being again well charged as at firſt, let a braſs wire bent in the form of a ſtaple be brought into contact with the upper and lower coating at the ſame time. By this the common diſcharge will be made; but the equilibrium of the coated glaſs will be only reſtored in part: for a conſiderable degree of attraction will happen at the ſame time between the upper coating and the glaſs, which has frequently been ſtrong enough to lift a piece of plate glaſs weighing ten ounces.* Neither coating will now ſhow the leaſt external ſign of electricity, while it is in contact with the glaſs; but on ſeparating either of them from it, if care be taken to preſerve their inſulations, the upper coating will be ſtrongly electrified negatively; and the under coating will be ſtrongly electrified poſitively. Let then both coatings be brought to their natural ſtate, by touching them when ſeparated from the glaſs, with a conducting body not inſulated, and let the glaſs be re-placed between them as before. In this ſtate of things, on touching the upper coating only, and ſeparating it from the glaſs, it will not be capable of giving any ſpark; but on touching the coatings alternately, five or ſix times, it will then give a weak ſpark; and this may now be repeated ſeveral times by only touching the upper coating: but on a ſecond application of the bent wire to both coatings at the ſame time, a ſecond diſcharge may be perceived, though much weaker than the firſt, and the coatings will be again brought into the ſame electrical ſtate, as immediately after the firſt diſcharge. This may frequently be repeated; and a conſiderable number of ſtrong negative ſparks may be taken from the coating, when it is ſeparated from the poſitive ſurface of the glaſs. If the glaſs in replacing it between the two plates be turned upſide down, the electrical powers of both coatings will be changed, by the next application of the diſcharging wire to complete the circuit; and a ſucceſſion of ſtrong poſitive ſparks may be taken from the coating, when it is ſeparated from the negative ſurface of the glaſs.

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* The whole of this effect muſt not be aſcribed to the attraction of electricity. Perhaps the paſſage of electric matter between the coating and the glaſs may help to exclude the air; and then the attraction of coheſion, and the preſſure of the external air both above and below, may be ſuppoſed to have the moſt conſiderable ſhare in producing this effect.

It appears from this part of the experiment, that the coated part of the charged glaſs was not brought into its natural ſtate, by completing the circuit between the coatings; but that it ſtill retained a degree of permanent electricity: that the powers of both coatings were actually changed, at the time of the firſt diſcharge; and that a ſucceſſion of the ſame powers may be produced in the coatings, without renewing the leaſt application of electricity to the glaſs itſelf.

Sect. 76. The whole quantity of electric matter added to the glaſs in charging it, is evidently diſtinguiſhed into two parts in this experiment. The firſt part, which is by far the moſt conſiderable, appears to have been readily communicated from one ſurface of the glaſs to the other, along the bent wire, when it was firſt brought into contact with both coatings at the ſame time. The ſecond part of the charge appears to be more permanent, and remains ſtill united with with the glaſs, notwithſtanding the circuit has been completed.* This permanent electricity, as well as the other muſt be poſitive on the upper ſurface, and negative on the lower ſurface; becauſe, in the preſent experiment, the charge was given by a ſmooth glaſs tube, excited with a ſilk rubber. Now, the influence of the oppoſite and permanent powers on the different ſides of the glaſs (each ſide having a tendency to bring the coating in contact with it into a ſtate of electricity contrary to its own) muſt aſſiſt each other, in cauſing part of the electric matter naturally belonging to the upper coating to paſs away from it to the under coating, along the diſcharging wire, and at the ſame time the ſurcharge paſſed the ſame way. The upper coating, therefore, by loſing ſome part of its natural quantity, muſt be negatively electrified, and the under coating by receiving an addition to its natural quantity, muſt be poſitively electrified. The whole quantity of electric matter, which the influence of the permanent electricity of the glaſs is capable of taking from one coating, and of adding to the other, bears but a ſmall proportion to the whole charge: and therefore, the ſecond and every ſubſequent diſcharge muſt be conſiderably weaker than the firſt.

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* Some new terms ſeem to be wanted, in order to expreſs with preciſion, the different parts of the charge. And if that part of it which cannot be deſtroyed by completing the circuit, ſhould be called the permanent part of the charge, or more ſimply the charge; then might the other part, or that, which may be deſtroyed by completing the circuit, be named the ſurcharge.

77. It appears from ſeveral of the preceding experiments, that a conſiderable degree of influential power may be produced at ſome diſtance, by an electric in full force; and therefore

a ſmall excited body of a cylindrical ſhape was ſufficient to anſwer that purpoſe: but when the excited electric has been ſo far weakened that it cannot communicate its own power, nor produce this influential power in any body, unleſs it be brought very near or in contact with it; bodies of a cylindrical form muſt then act to great diſadvantage, and a ſmall degree of power only can be produced, as in the experiment, § 44; becauſe the ſtrength of the influential electricity in this caſe, will be in proportion to the ſurfaces of the electric and conducting bodies, which are brought near together, or in contact with each other; and therefore a plate of glaſs in the ſame circumſtances, whether its permanent power be derived from excitation or communication, is enabled from its ſhape to produce a conſiderable degree of the influential powers, in the coatings in contact with it.

Sect. 78. It appears from this experiment that the ingenious profeſſor Volta's electrophorus is, in reality, a reſinous plate charged with permanent electricity by friction: and becauſe there is a leſs diſpoſition in a body of this kind to attract moiſture from the atmoſphere, than there is in glaſs; it will retain the power better, and conſequently be the longer capable of producing a contrary electricity in the inſulated metal cover. If it ſhould be thought neceſſary to ſupport this obſervation, by a direct experiment; it may eaſily be done by making a thin flat plate of any reſinous electric ſubſtance, and larger than the inſulated cover, but without faſtening a coating to either ſurface; and then whether this plate be charged by excitation or communication, one of its ſides will be poſitive, and the other ſide negative; and a ſucceſſion of poſitive ſparks may be produced on the negative ſide, and of negative ſparks on the poſitive ſide, by a proper application of the inſulated metal cover. It will be alſo found, that this reſinous plate cannot be well charged, either by excitation or communication, unleſs a coating of ſome conducting matter ſhould be kept in contact with the under ſurface; and it ſhould alſo have ſome communication with the floor.

Sect. 79. It has been very properly recommended to uſe a particular kind of rubber, and to attend to the ſtate of it, in order to excite glaſs well; but it will not be neceſſary to pay the leaſt regard to theſe circumſtances in the following experiments, in which a method will be ſhown of charging a ſmall phial and a plate of glaſs at the ſame time, by a gradual accumulation of power; that power being entirely derived from the glaſs itſelf, and with no other degree or kind of friction, than is neceſſarily connected with the form of the experiment.

EXPERIMENT XXIII.

The Conſtruction.

Sect. 80. Place a circle of tinfoil five inches in diameter on the table, between a ſoft piece of baize and the middle of the ſame plate of glaſs that was uſed in the laſt experiment, which will thus be coated on the under ſide; and in order to preſerve a proper communication with this coating, let a fillet of tinfoil reach from it beyond the extremity of the glaſs. The ſame inſulated metal cover is to be uſed for the upper coating, as before. Let a thin ounce phial of glaſs be filled with braſs filings, and coated with tinfoil on the outſide, to about one inch from the top. Let a large braſs wire, the fifth part of an inch in diameter, paſs through the cork of the phial into the filings, about an inch of it being left above the cork, and let the upper extremity of this wire be well rounded. This experiment, as well as the laſt, requires, that the whole conſtruction ſhould be well warmed at firſt, and it will be neceſſary to repeat it at proper intervals, unleſs the atmoſphere ſhould be very dry.

Taking hold of the wire of the phial with one hand, let it be placed on the upper ſurface of the glaſs, and its bottom carried in contact over the middle of the upper ſurface, as far as the tinfoil coating reaches on the under ſide: and during this part of the operation, a finger of the other hand muſt be kept in contact with the fillet of tin-foil. Then lifting the phial by the wire with one hand, let it be placed on the inſulated metal cover, ſuſpended in the air with the other hand; and after ſhifting the hand from the wire to the coating, let the bottom of the phial be placed on the end of the tinfoil fillet. Place the inſulated metal cover on the middle of the glaſs, and touch it with a finger of one hand, while the other hand touches the tinfoil fillet. Now lift the inſulated cover by its ſtem, and bring the bead of the cover in contact with the wire of the phial, and a very ſmall ſpark of light will appear between them. Let this be repeated in the ſame manner about fifteen times, taking care to preſerve a proper communication between the coating and the floor. Then taking hold of the phial by the coating, let it be replaced on the inſulated cover, while it is ſuſpended in the air; and after ſhifting the hand from the coating to the wire, let it be again placed on the middle of the glaſs, and let the bottom be again carried in contact over the middle of the glaſs, holding the wire in one hand, while the other has a proper communication with the tinfoil coating. Let the phial be again returned to the tinfoil fillet as before, and let the inſulated cover be applied repeatedly to the wire, immediately after every ſeparation from the glaſs; and a brighter ſpark together with a weak ſnapping, will now attend each application, if it be carefully obſerved to touch the cover with one hand before every ſeparation, while the other hand reſts on the fillet of tinfoil. By proceeding in this manner, after the third application of the phial to the glaſs, a very weak ſhock will be felt in thoſe fingers which are uſed in completing the circuit of the glaſs; and after repeating two rounds more in the manner before mentioned, the phial will be fully charged. By applying the coating of the phial when it is in full force to the upper ſurface as before, the glaſs plate will get the greateſt power it is thus capable of receiving, and will then give a ſhock as high as the elbows. After this, on attempting to lift the inſulated cover, the glaſs itſelf will generally be lifted at the ſame time, with the tinfoil coating adhering to the under ſurface: but by continuing the ſeparations of the cover from the glaſs, a ſucceſſion of ſtrong negative ſparks may be prodused by the influence of the upper ſurface, and by turning the glaſs over, and leaving the tinfoil coating on the baize, a ſucceſſion of ſtrong poſitive ſparks may be produced by the influence of the otherſide.

This experiment may be performed more ſteadily by placing the glaſs, together with the tinfoil coating and baize, on a plate of metal, about one tenth of an inch thick, and of the ſame ſquare as the glaſs. The whole may be faſtened together by two ſmall holdfaſts placed at the oppoſite corners, which will prevent the glaſs from being lifted. This plate of metal will be uſeful in another view; for after it has been ſufficiently warmed, by retaining heat well, it will help to keep the glaſs dry, and conſequently fit for uſe ſo much the longer. But when it ſhall be required to ſhow the contrary powers of the oppoſite ſides of the glaſs, it will be more convenient not to faſten the parts together, and the whole may be kept ſufficiently ſteady, by the operators keeping down one corner of the glaſs with a finger, and by placing a proper weight on the oppoſite corner.

Sect. 81. The bottom of the phial cannot be carried in contact over the glaſs, without producing ſome little degree of friction; from which the power in this experiment is originally derived. The cover will appear on examination to be electrified negatively, after every ſeparation from the glaſs: but as it was touched in completing the circuit between the coatings, before every ſeparation; it neceſſarily follows, that the cover can have only an influential electricity, and conſequently that the permanent power of the upper ſurface of the glaſs muſt be poſitive. The negative power of the cover is communicated to the wire of the phial, by which the inſide is electrified negatively, and the outſide poſitively, and both theſe powers will increaſe with every application, becauſe the circumſtances of the phial are favourable to its charging. The phial muſt be inſulated every time it is required to ſhift the hand from the wire to the coating, or from the coating to the wire; for without this precaution the phial would be diſcharged. By applying the outſide of the phial to the upper ſurface of the glaſs, in the manner above mentioned, the phial will be partly diſcharged on that ſurface: and though it muſt be therefore weakened, the power of the glaſs will be increaſed, and conſequently enabled to produce a proportionably ſtronger effect on the braſs cover, which by the next round of applications, will give the phial a ſtronger charge than it had before. And thus a very ſmall degree of original power is firſt generated and then employed in forming two different accumulations: and by making each of theſe ſubſervient to the increaſe of the other, the phial is at laſt fully charged, and the glaſs plate acquires ſuch a degree of the ſurcharge, as to give a pretty ſmart ſhock; and after that it remains capable, by the influence of its permanent powers, of producing a ſucceſſion of poſitive and negative ſparks, on the oppoſite ſurfaces.

Sect. 82. The contrary charge may be given to the phial by taking hold of the coating, and carrying the wire in contact over the middle of the upper ſurface of the glaſs, and by applying the power of the inſulated cover to the coating; for if the operation be conducted in every other reſpect, in the ſame manner as before, then will the inſide be electrified poſitively, and the outſide negatively. The powers of the glaſs plate will be the ſame as they were in the former caſe.

EXPERIMENT XXIV.

Sect. 83. It is deſigned to determine, in this experiment, what effects may be produced, by making the contrary powers of the phial and glaſs plate act in oppoſition to each other.

First Part.

After the phial has been fully charged negatively, by the proceſs of the laſt experiment, let it be inſulated, and taking hold of the wire, let the bottom be held uppermoſt, and let the hand which holds it reſt on the fillet of tin-foil. Apply the inſulated cover to the glaſs, and after touching it with a finger of the other hand, ſeparate it from the glaſs; and on bringing it towards the coating of the phial, a ſtrong ſpark will paſs between them. After repeating this between twenty and thirty times, the powers of the phial will be deſtroyed; and by continuing the ſame operation, they will be inverted; for the inſide will be at laſt fully charged poſitively, and the outſide negatively.

The ſame effect may be produced, by turning the glaſs over, and by repeatedly applying the influential electricity, produced on that ſide, to the wire of the phial.

SECOND PART.

When the phial has been fully charged negatively, as in the laſt experiment, take hold of the coating of the phial with one hand, and, while the other hand reſts on the tinfoil fillet, apply the wire to the middle of the upper ſurface of the glaſs, as far as the tin-foil coating extends on the other ſide. By this the powers of the glaſs plate will be changed.

Another, and perhaps a better method of applying the phial, is, to place the inſulated cover on the ſurface of the glaſs, and then holding the phial by the coating in one hand, to apply the wire to the cover, while the other hand touches the fillet of tin-foil; by which a ſhock will be given, and the ſame change of powers will be produced in an inſtant, which before took up ſome little time. On lifting the inſulated cover by its ſtem, immediately after the ſhock, it will be negative, or have the ſame power as the inſide of the phials; but on replacing the cover, and completing the circuit of the glaſs plate, the ſurcharge will be deſtroyed; another ſhock will be felt; and the power of the cover, after the next ſeparation, will be poſitive, or contrary to that of the inſide of the phial.—See the ſecond part of the twenty-ſecond experiment. Apply this poſitive power to the wire of the phial, as before; and after fifteen applications, the powers of the phial will be deſtroyed; and by ſtill proceeding in the ſame manner, the powers of the phial will be changed, and the inſide will be fully charged poſitively, and the outſide negatively, by ſixty applications.

Theſe effects may alſo be produced by a ſingle application of the coating of the phial to the other ſide of the glaſs plate; and by repeated applications of the influential electricity, produced on the ſame ſide, to the coating of the phial.

Sect. 84. If it were ſimply the object in this experiment, to change the powers of the phial, the operation might then be conſiderably ſhortened, by completing the circuit of the phial, and conſequently deſtroying the whole ſurcharge:

but it was intended to ſhow what effects might be produced, by oppoſing the contrary powers to each other; and by doing this it appears that either ſide of the glaſs plate can deſtroy the powers of the phial, and give it a contrary charge; that either ſide of the phial can alſo change the powers of the glaſs plate; and that the powers of the glaſs plate thus inverted, can again deſtroy the powers of the phial, and give it a full charge of the contrary electricity.

Sect. 85. The needle deſcribed in § 39, being electrified, may be conveniently uſed to examine the electricity of any other body, and will be particularly uſeful for this purpoſe in the two laſt experiments, by placing it at the diſtance of twelve or fourteen inches from the phial. When the inſulated cover and phial are weakly electrified, they muſt be carried towards the needle to determine their quality: but as the power increaſes, the needle will be either attracted or repelled at the whole diſtance, immediately on every ſeparation of the cover from the glaſs, and thus ſhow whether the cover be in a poſitive or negative ſtate. When the inſide of the phial has been fully charged with the ſame power as the needle, the wire can only repel the needle at a conſiderable diſtance; but as ſoon as it has received a full charge of the contrary electricity, the power of the needle will be immediately deſtroyed; and this effect may be produced even at the diſtance of two feet, by going on with the application of the electrified cover to the wire of the phial. If the phial be kept in full force one minute, by repeated applications of the cover, and it be allowed alſo to remain in its place, the air contained within the limit before mentioned, will acquire ſo much of the ſame electricity as the inſide of the phial, that on giving a contrary power to the needle again, it will not retain that power well, though it will retain the other power as well as before. In order to ſhew the laſt mentioned effect, it will be proper to give the contrary electricity to the needle the ſecond time by influence, and not by communication: becauſe, it is difficult to give the needle a full charge by communication, without giving it more than it can poſſibly retain; and which would certainly weaken, if it ſhould not be ſufficient to deſtroy the contrary power already communicated to the air. See the ſeventeenth experiment, in which the electricity of a pair of vertical needles was deſtroyed at the diſtance of nine inches, and through the air, by communicating to another pair of needles a greater degree of the contrary power than they were capable of retaining. § 55 to 60.

Sect 86. Here it may be obſerved, that in ſome caſes, the quality of the power may be determined by obſervation alone. When the phial employed in the two laſt experiments has been fully charged, it may be known whether the inſide be poſitive or negative, from the light which appears at the wire; or from the hiſſing noiſe which attends it: for when the phial has been fully charged poſitively, if the room be ſufficiently darkened, a bright luminous appearance may be ſeen, diverging in ſeparate rays to the diſtance of an inch, attended with an interrupted hiſſing noiſe; and both the light and the noiſe continue a very ſhort time. But when the phial is fully charged negatively, a weaker and more uniform light appears, which does not extend itſelf more than the ſixth part of an inch, and is attended with a cloſer and more uniform hiſſing; and this noiſe and light always continue longer than the former. Even poſitive and negative ſparks, paſſing between the inſulated cover and a finger, may be diſtinguiſhed from each other: for, the poſitive ſparks are more divided, give leſs light, make a weaker ſnapping noiſe, and affect the finger leſs ſenſibly than the negative.

The ſtrongeſt ſparks which can be produced in theſe experiments, are thoſe that paſs between the coating of the phial and the inſulated cover, when they poſſeſs contrary powers; but they will be more particularly vigorous, if the coating be poſitive, and the inſulated cover negative.

ELECTRICAL EXPERIMENTS,

AND

OBSERVATIONS.

PART III.

Obſervations on ſome of the Effects produced in the Air by Electricity.

SECTION 87.

THE air deſerves to be particularly conſidered, becauſe it is the place, or theatre, in which both natural and artificial electricity are exhibited. And, notwithſtanding a ſmall portion of the air cannot be ſo eaſily taken from the reſt, and examined apart, as may be done in ſolid electric bodies, yet by carefully attending to every circumſtance, ſomething may be known of the effects which a ſmall excited electric may be capable of producing on the air itſelf: and in thoſe caſes which will not admit of a direct experimental proof, ſome evidence may be derived from analogy, by obſerving how other electric bodies are affected by the ſame power.

Sect. 88. The air has been univerſally acknowledged to be an electric ſubſtance. It has been ſhewn before, in the 29th and 52d ſections, to be one of the moſt perfect electrics, or to have leſs of the conducting quality, than any other body. It alſo appears from the 17th experiment, that when a greater power was communicated to a pair of vertical needles, than they were capable of retaining, that ſuch a change would be produced in the adjoining air, as to deſtroy the contrary power of another pair of needles, at the diſtance of nine inches.—§. 55 to 60, 85.

Sect. 89. It will be now proper to conſider a little, what effects are likely to be produced on the air, in a different ſtate of things: namely, in the air ſurrounding an excited electric; but without continuing the excitation any longer than may be neceſſary to excite it fully: or, in the air ſurrounding a conducting body, inſulated and electrified; but without continuing the communication with the electrifying power any longer than may be neceſſary to give that body all the electricity it is capable of retaining.

It has been already obſerved, that in a dry ſtate of the atmoſphere, a ſmall ſtick of excited ſealing-wax, and alſo an electrified pair of vertical needles, were capable of retaining ſome part of their electricity for many hours.—§. 25. 28.

28. But, as both were obſerved gradually to grow weaker, there muſt have been ſome conveyance for the electric fluid, either to or from the needles, and the ſealing-wax. And as the air muſt neceſſarily have been in contact with the ſurfaces of both, during the whole time, it is not improbable, that ſome ſmall part of the electric matter might paſs that way. But if it be admitted, that amber and ſealing-wax are better conductors than air, it follows, that a conſiderable part of the electric matter neceſſary to reſtore the equilibrium, muſt have paſſed ſlowly along the ſurface of the amber, or the ſealing-wax, and not immediately to or from the air. It appears from a great variety of experiments, that all electric bodies, when they are quite dry, receive or part with the electric fluid with much more difficulty than better conducting ſubſtances: and as air is certainly one of the worſt conductors, §. 29. 52. it is not probable that either a poſitive or a negative power can be communicated immediately to the air in thoſe circumſtances, in which the ſame cannot be communicated to any other electric body, nor even to the beſt conductor. But it appears that no immediate communication can be made, either to an electric body, or to a conductor within the ſphere of influence, and conſequently the ſame thing muſt hold true with regard to the air itſelf. Moreover, it has been ſhewn, that

thoſe extremities of the needles made of electric ſubſtances, which were the neareſt to the acting power, but within the ſphere of influence, were brought into a ſtate of contrary electricity; and that the other extremities were brought into the ſame ſtate of electricity as the power itſelf: §. 49. 51. and as it is highly probable that the air, in this reſpect, is alſo affected in the ſame manner as other electric bodies; it therefore follows, that ſome of the electric matter naturally belonging to the air is ſhifted from ſome parts of it to others, by which both a poſitive and negative electricity are produced at the ſame time, in different parts of the air, by the influence of an electric power.

Sect. 90. From what has been obſerved in the preceding ſection, it is evident that neither an excited electric, nor an electrified conductor, in the circumſtances above mentioned, can poſſibly be ſurrounded with an electric atmoſphere of the ſame kind; but that the air ſurrounding both theſe bodies muſt neceſſarily have a contrary electricity, in the whole ſphere of influence.

Sect. 91. It appears from the 51ſt ſection, that the contrary electricities produced in amber or tortoiſeſhell, by the influence of an electric power, will continue for ſome time after the power is removed; but no ſuch permanent effect in the air has been obſerved to attend the uſe of theſe ſmall electrics. This difference may be aſcribed to the fluidity of the air. In ſolid electrics, the equilibrium will be reſtored ſooner or later, as they poſſeſs more or leſs of the conducting quality. But in the yielding ſubſtance of the air, as ſoon as the influence of the power is removed, the parts of the air which have acquired contrary electricities, or thoſe which have acquired different degrees of the ſame power, may eaſily approach each other, in conſequence of their mutual attraction, ſo as to reſtore the equilibrium in a very ſhort time.—An imperfect experimental illuſtration of this account of the matter may be ſeen in the ſixteenth experiment. §. 54.

Sect. 92. It appears from the eleventh and the twentieth experiments, that the influence of an excited electric was not only capable of deſtroying a power of the ſame kind, communicated to a pair of vertical needles, or to the middle of a plate of glaſs, but alſo of producing a contrary electricity in both caſes. §. 36, 37, 68. And, as the power of the needles, and of the plate of glaſs, were of a permanent nature, and conſequently attended with a contrary electricity, in their reſpective ſpheres of influence, §. 90. it follows, that in producing theſe effects the power in the ſphere of influence, in both caſes, muſt have been firſt weakened, then deſtroyed, and at laſt changed to the contrary electricity. From hence, therefore, it is reaſonable to believe, that when two ſpheres of influence of the ſame kind, are brought ſo near together, that their moſt diſtant limits interfere, they muſt weaken each other. Here it may be proper to refer to all thoſe parts of the preceding experiments and obſervations, in which a contrary electricity was produced by the influence of an electric power; and which have evidently a relation to the preſent caſe; becauſe, weakening the ſame power, and producing an equal degree of the contrary power, are different expreſſions perfectly conſiſtent with each other; the former ſignifying an event in a particular circumcumſtance, and the latter pointing out the means by which that event muſt certainly be produced.

The influence of an electric power appears to produce a contrary electricity on conducting ſubſtances, from §. 9, 11, 16, 19, 20, 23, 30, 34, 35, 36, 37, 38. The ſame cauſe appears to produce a ſimilar effect on electric bodies from §. 45, 48, 49, 51, 53, 54, 66, 67, 68, 69, 70, 71.

Obſervations on Electric Repulſion.

Sect. 93. Bodies having the ſame electricity recede from each other, and are therefore ſaid to be in a ſtate of repellency. But as the reaſon generally aſſigned for this effect, namely the electricity of the electric fluid, is not ſo applicable to bodies electrified negatively, as it ſeems to be to thoſe electrified poſitively, it may not be improper to attempt ſuch an explanation of this matter, as may be equally applicable to both powers, becauſe it is reaſonable to believe, that the ſame appearance in both caſes muſt proceed from one and the ſame cauſe.

Sect. 94. Let an ivory horizontal needle be inſulated and electrified either poſitively or negatively, and if the reaſoning in the 89th ſection be admitted, the air in the ſphere of influence belonging to this needle muſt have a contrary power, (§ 90) and will therefore attract the needles: but as the air ſurrounds it on every ſide, this attraction being equal in contrary directions, the needle will not have the leaſt motion on that account: but on approaching one end of the needle ſideways, with a power of the ſame kind as was given to the needle, till the ſphere of influence belonging to that power reaches the air contained in the ſphere of influence belonging to the needle, and then the electrical ſtate of the air, and its conſequent attraction of the needle on this ſide, muſt be leſſened by the influence of a power of the ſame kind brought towards it, by §. 92. But the air on the other ſide of the ſame end of the needle remaining nearly in the ſame ſtate* as in the beginning, muſt ſtill continue to attract the needle as ſtrongly as before, and will therefore give it a motion that way. And thus a needle electrified either poſitively or negatively, will have the appearance of being repelled, by a power of the ſame kind brought towards it, though it be really attracted by the air on the other ſide.

Sect. 95. It is hardly neceſſary to obſerve that the ſame principle will alſo account for an electrified needle being attracted by a contrary power, which, by increaſing the electricity in the air on that ſide of the ſphere of influence belonging to the needle towards which the power is brought, muſt neceſſarily give it a contrary motion to what it had in the other caſe.

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* It is highly probable that the electricity of the needle on this ſide, and alſo the contrary power in the correſponding part of the ſphere of influence, muſt be increaſed a little by the approach of the excited electric to the other ſide of the ſame end of the needle, and conſequently the needle will be more ſtrongly attracted on this ſide than it was at firſt.

Sect 96. Thus it appears that the motion of a body electrified either poſitively or negatively, on bringing an electric power of either kind towards it, may be aſcribed to the changes produced in the electrical ſtate of the intermediate air; and conſequently, that the air thus changed is the medium which enables one electrified body to act upon another at ſome diſtance.

Obſervations on the Electrified Cup.

Sect. 97. Dr. *Franklin* relates the following curious and ſingular experiment, in his letter to Dr. *L.* of the 18th of March, 1755.

> " *I electrified a ſilver pint cann, on an electric*
> " *ſtand, and then lowered into it a cork ball of*
> " *about an inch diameter, hanging by a ſilk ſtring*
> " *till the cork touched the bottom of the cann.*
> " *The cork was not attracted to the inſide of the*
> " *cann as it would have been to the outſide, and*
> " *though it touched the bottom, yet when drawn*
> " *out it was not found to be electrified by that*
> " *touch, as it would have been by touching the*
> " *outſide.*"*

The electrified cup muſt certainly act in a different manner on the ball lowered into its cavity, and on the ball brought towards the

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* FRANKLIN's Experiments, &c. p. 325.

outſide; becauſe in one caſe the influence of the whole internal ſurface acts on different parts of the ball at the ſame time; but in the other caſe, the influence only of a part of the external ſurface can act on that ſide of the ball which is the neareſt to it. On this ground ſome explanation of the experiment may be attempted in the following manner.

Sect. 98. It appears in the firſt part of theſe experiments, that every conducting body, whether it be inſulated or not, is attracted by an electric power within the whole ſphere of influence, and that the attracted part acquires at the ſame time a contrary electricity: and as it appears alſo, that this contrary power encreaſes, as the diſtance from the ſphere of communication decreaſes, it follows, that a contrariety of power muſt always precede, and ought therefore to be conſidered as the immediate and neceſſary cauſe of all attraction, and of every communication of electricity. Now with regard to the experiment under conſideration, the only means of producing a temporary power of either kind, on any particular part of the inſulated cork ball, muſt be by ſhifting ſome of the electric matter naturally belonging to the ball either to or from that part: but the influence of the inſide of the electrified cup, ſeems likely to prevent any ſuch effect; for when the ball is lowered into its cavity, the influence of the whole inſide of the veſſel acting on all the different parts of the ball at the ſame time, muſt by its tendency to produce a contrary electricity on every part in general, prevent that effect from being produced on any particular part. And when the ball is brought into contact with the bottom, or any other part of the inſide, it is very improbable, that the influence of a ſmall part of the inſide towards which the ball may be brought, ſhould be capable of counteracting the united influence of all the reſt of the inſide, on the other parts of the ball; and unleſs this ſhould be done, and the approaching part of the ball ſhould firſt have acquired ſome degree of a temporary electricity, contrary to the permanent power of the cup, it can neither be attracted to the inſide, nor receive any part of the power of the cup from contact.

Sect. 99. If the upper part of the ball be held above the top of the cup, and it be thus brought towards the inſide, it will be attracted. Becauſe as the influence of no part of the veſſel can now act on the upper ſide of the ball; and as the influence of ſeveral of the other parts of the inſide muſt now act at a greater diſtance than before, therefore the influence of the ſmall part of the inſide towards which the ball is brought, will be capable of bringing the approaching part of the ball into a ſtate of contrary electricity, and conſequently, the ball will, in this caſe, be attracted by the cup, and receive ſome power from touching the upper part of the inſide.

Sect. 100. When the ball is brought towards the middle of the outſide, it will be more ſtrongly attracted, and receive more of the power of the cup from contact, than it could in the laſt caſe, becauſe the influence of that part of the outſide towards which the ball is brought, muſt exert its whole force on one ſide of the ball only, without the leaſt controul from the ſame kind of influence acting on different ſides of the ball at the ſame time.

Sect. 101. It may not be improper to illuſtrate the preceding explanation, §. 98. by ſhewing in a different manner, that the influence of an electric power acting on an inſulated conducting body, in its natural ſtate, may prevent that body from receiving the leaſt degree of the ſame electricity, on touching another body fully electrified.

Let a well excited electric be held parallel to the frame of a pair of vertical needles, in their natural ſtate, and as near as poſſible to the frame, without being within the communicating diſtance. Let the communicating wire of this pair touch the communicating wire of a ſecond pair of needles, fully electrified with the ſame electricity as the excited body. After the contact, let one pair be ſeparated from the other, and then on removing the excited electric, the firſt pair of needles will be found to be ſtill in their natural ſtate, notwithſtanding the communicating wire belonging to them has touched the communicating wire of the ſecond pair of needles, which were fully electrified. This in fact was the real ſtate of things in the former part of the experiment. § 34.

It appears alſo, from the latter part of the ſame experiment, that the influence of an excited electric on a pair of vertical needles, poſſeſſing a contrary electricity, may be ſo managed, as to prevent any communication of power from theſe to another pair of needles in their natural ſtate, notwithſtanding the communicating wire of the two pair ſhould be brought into contact.

Sect. 102. If any further illuſtration ſhould be thought neceſſary, the communicating wire of a pair of vertical needles, poſſeſſing their natural ſhare of electric matter, may be made to touch one of theſe ſmall excited electrics; or the outſide of the electrified cup; or even the knob of a four ounce phial fully charged, without receiving electricity from either, provided the oppoſite ſide of the frame be kept under a proper degree of influence of the ſame electricity, as long as the communicating wire ſhall remain within the ſphere of communication.

Obſervations on the Analogy between Electricity and Magnetiſm.

Sect. 103. Several writers have mentioned the ſimilar appearances of electricity and magnetiſm, in particular experiments; and the analogy will be rendered ſtill more ſtriking, by conſidering the effects of an electric power on different ſubſtances, formed into proper needles. It is however the influential electricity, and that only in particular circumſtances which bears the neareſt reſemblance to magnetiſm. The experimental philoſopher may find it of ſome uſe to remember theſe ſimilitudes: but a regard to truth requires alſo his attention to other circumſtances, which plainly ſhow theſe powers to be eſſentially different. Some of the moſt remarkable circumſtances of this kind are contained under the following particulars.

I. Electricity may be raiſed in a great variety of very different ſubſtances, and is then capable of being communicated to all bodies in general: but magnetiſm is confined to one particular kind of matter, both in its origin and communication.

II. The tourmalin, and a few other ſtones, may be excited by heat alone; though the generality of electric ſubſtances will not act without

out friction. On the other hand, magnetiſm may be produced in the firſt inſtance by poſition alone, without either heat or friction.

III. Inſulation is a neceſſary part of almoſt every electrical experiment, and no good conducting body can retain even a ſmall degree of this power without it: but nothing of a ſimilar nature appears to have the leaſt relation either to the retention or communication of magnetiſm.

IV. A conſiderable degree of heat deſtroys both electricity and magnetiſm: and yet a moderate warmth, ſuch as is found to be favourable to electricity in every reſpect, moſt certainly weakens a magnetic power; as appears from the late Mr. *Canton*'s curious obſervations and experiments on the diurnal variation of the magnetic needle.

V. Moiſture is particularly unfavourable to electricity; but magnetiſm is ſo far from being affected by it, that it is not in the leaſt weakened by acting through water itſelf.

VI. Electricity is capable of acting through electric ſubſtances, but with ſome diminution of power; and this action is prevented by the interpoſition of every other body. Magnetiſm, on the contrary, cannot act through magnetic bodies, though it can through all others, and without the leaſt diminution of power.

VII. Every pointed conducting body weakens an electric power at ſome diſtance; but nothing of the ſame kind has been obſerved in magnetiſm.

VIII. No ſubſtances are capable of retaining any conſiderable degree of electricity in the exhauſted receiver of an air pump: * but a magnetic body retains the whole of its power, and acts with equal force, whether it be ſurrounded with air or not.

IX. Electricity may be perceived by every one of the ſenſes, either in its origin or communication: but, the production and communication of magnetiſm are not attended with any ſenſible evidences; neither can it be certainly known whether a body has received a magnetic power or not, without bringing it to the teſt of ſome experiment, and obſerving how that body and others of the ſame kind mutually act upon each other.

X. Electricity appears to have no immediate relation to the poles of the earth: but polarity is

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* It appears probable that no ſubſtances could retain the leaſt degree of electricity in a perfect vacuum.

is the peculiar and diſtinguiſhing characteriſtic of magnetiſm.

XI. The whole of any ſubſtance may be made electrical, either poſitively or negatively: but in every communication of magnetiſm, there will always be a north and a ſouth pole in the ſame body, be it ever ſo ſmall.

XII. Electricity is either deſtroyed or weakened by every communication with other bodies: magnetiſm, on the contrary, is either preſerved or ſtrengthened by a communication of that power.

XIII. In electricity, the poſitive and negative powers will in ſome caſes preſerve, and in other caſes deſtroy each other: but, in magnetiſm, the poles of a different denomination will always preſerve or ſtrengthen each other.

XIV. The ſtrengthening a magnetic power in any body, will only enable it to lift a heavier weight, or to attract and repel the different ends of a magnetic needle at a greater diſtance, or to communicate this power more readily to other bodies of the ſame kind: but the greateſt degree of magnetiſm cannot produce the leaſt reſemblance to any of thoſe various effects, which may be produced by the accumulation of an electric power. Electricity is fire itſelf, or ſo intimately united with it, that when it is collected in a ſufficient quantity, and properly diſcharged, it becomes capable of firing different ſubſtances; of rending ſome bodies to pieces; of melting and calcining metals; of deſtroying both animal and vegetable life; and of producing all thoſe wonderful effects, which have been obſerved to be produced by lightening.

Here it will be proper to ſtate particularly, that a ſtroke of lightening has given polarity to ſteel; and that the ſame effect has been produced by ſending a ſtrong charge of electricity through a common ſewing needle. This obſervation may help to eſtabliſh the ſameneſs of electricity and lightening, if it be taken in conjunction with a variety of other circumſtances, in which they alſo agree: but as there is no other experimental proof of a real connexion between electricity and magnetiſm, and as theſe powers appear to be unlike in ſo many other particulars, they ought certainly to be conſidered as being eſſentially different, unleſs future diſcoveries ſhould produce ſome other unqueſtionable evidence of their connexion, beſides the ſolitary fact abovementioned; which can prove but little in the preſent caſe; eſpecially if it be conſidered, that the ſtroke of a hammer will alſo communicate to ſteel the ſame polarity.

The

The CONCLUSION.

IT appears from a review of the preceding experiments and obſervations, that an electric power attracts every ſubſtance which is placed within the ſphere of its influence, whether it be an electric or a conductor, and at the ſame time brings the neareſt part of the attracted body into a ſtate of contrary electricity. So that, ſtrictly ſpeaking, the oppoſite powers only attract each other, and no ſubſtance is ever attracted, before the attracted part has acquired a contrary electricity. And as it is the conducting quality which enables any body to be brought into a contrary electrical ſtate, if any particular ſubſtance ſhould be diſcovered in future, to be abſolutely a non-conductor, it is apprehended that ſuch a ſubſtance would not be capable of being attracted by electricity, nor of receiving either a poſitive or a negative power. It appears alſo, that when the influence of an electric power acts on any electrified ſubſtance, it muſt, by its tendency to produce a contrary electricity, deſtroy or weaken the ſame power, and preſerve or ſtrengthen the contrary power, according to the different circumſtances of the caſe. When two bodies, having the ſame electricity, recede from each other, this effect has generally been referred to the principle of repulſion: but ſome attempt has been made to ſhew, that it may be aſcribed to a change produced in the electrical ſtate of the air by the receding bodies, and that this change occaſions the air to attract them in contrary directions. The influence of electricity has been ſhewn to act in the ſame manner through glaſs, as it does through the air; and the principal phenomena of the charged phial appear to be eſſentially the ſame with thoſe of any other electrified body. In one reſpect, however, they are certainly different; for on conſidering the nature of a charged plate of glaſs, it appears from a direct experiment, that the glaſs is not brought into its natural ſtate by completing the circuit between the two coatings; but that ſuch a degree of the poſitive and negative powers are ſtill ſo permanently united with the oppoſite ſides of the glaſs, as to enable them to produce the influential electricities in their reſpective coatings for ſome time: and on this ground the effects produced by Mr. *Volta*'s electorphorus may be readily explained. The poſitive and negative powers are ſo inſeparably united, that one cannot be ſhewn without actually producing the other, notwithſtanding it may not eaſily be obſervable in ſome particular caſes. This ſtrict union between the two powers ſeems to be deſigned as a preparatory and leading ſtep, to promote the reſtoration of the equilibrium: and when the united efforts of both (of the poſitive to part with its redundancy and of the negative to receive its deficiency) are ſuperiour to the reſiſtance of the intermediate air, a communication muſt be made from the poſitive to the negative through the air; by which the equilibrium will be in part reſtored. And all the variety of electrical experiments we can perform, appear to be no more than different modes of deſtroying or reſtoring the equilibrium. By deſtroying it, a poſitive and a negative power are produced at the ſame time. By reſtoring it in part both theſe powers are weakened; and when the reſtoration is completed, all things return again to their natural ſtate, and every appearance of electricity ceaſes.

FINIS.

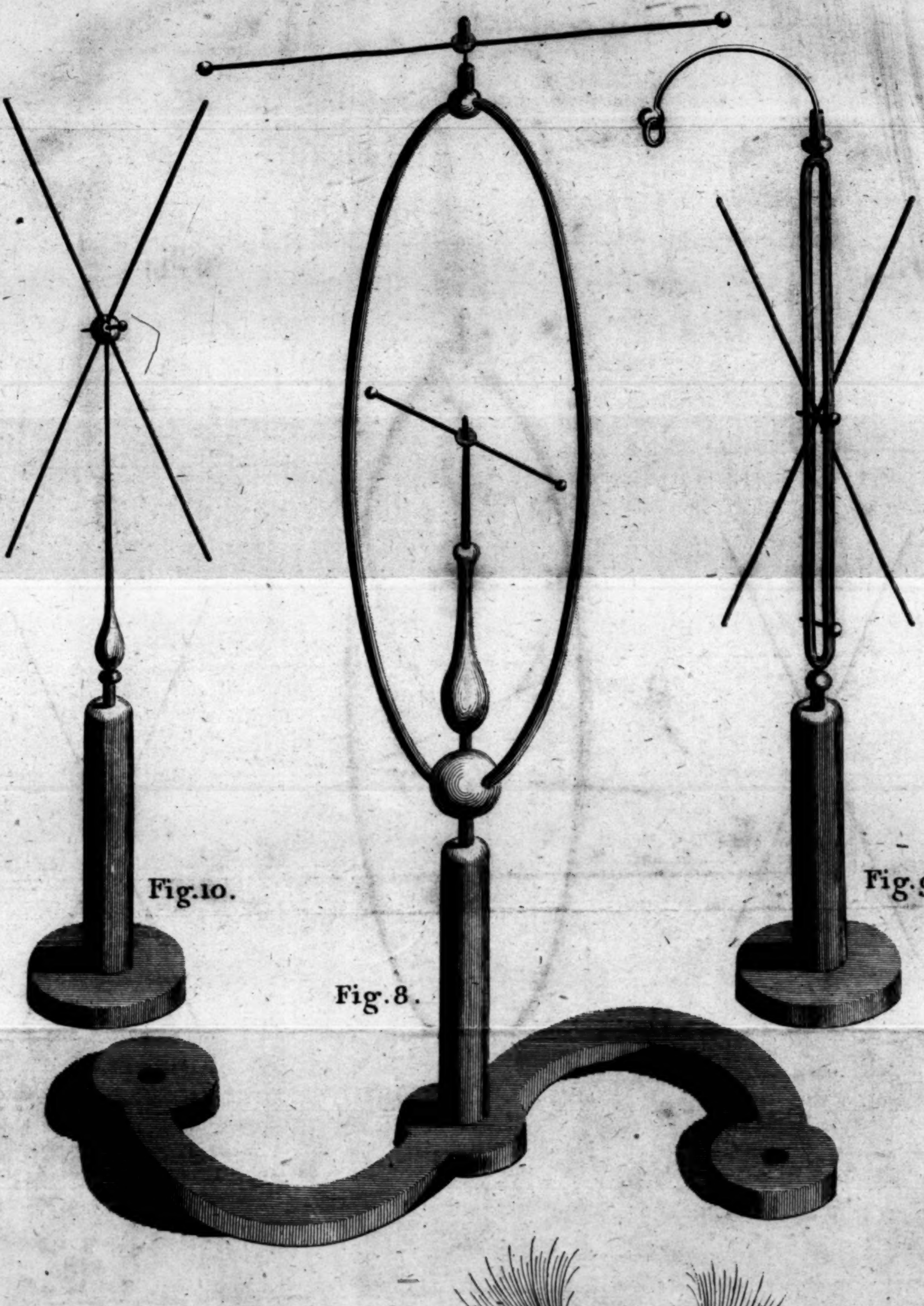
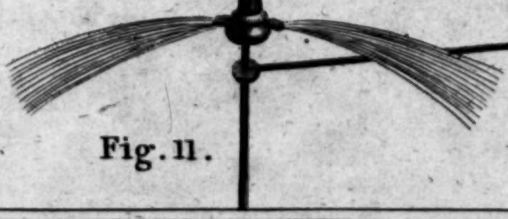


Fig. 10.

Fig. 8.

Fig. 9.



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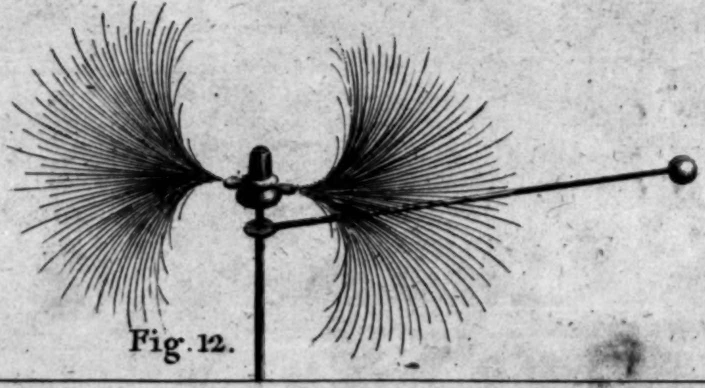

Fig. 12.

Jn. Lodge sculp.

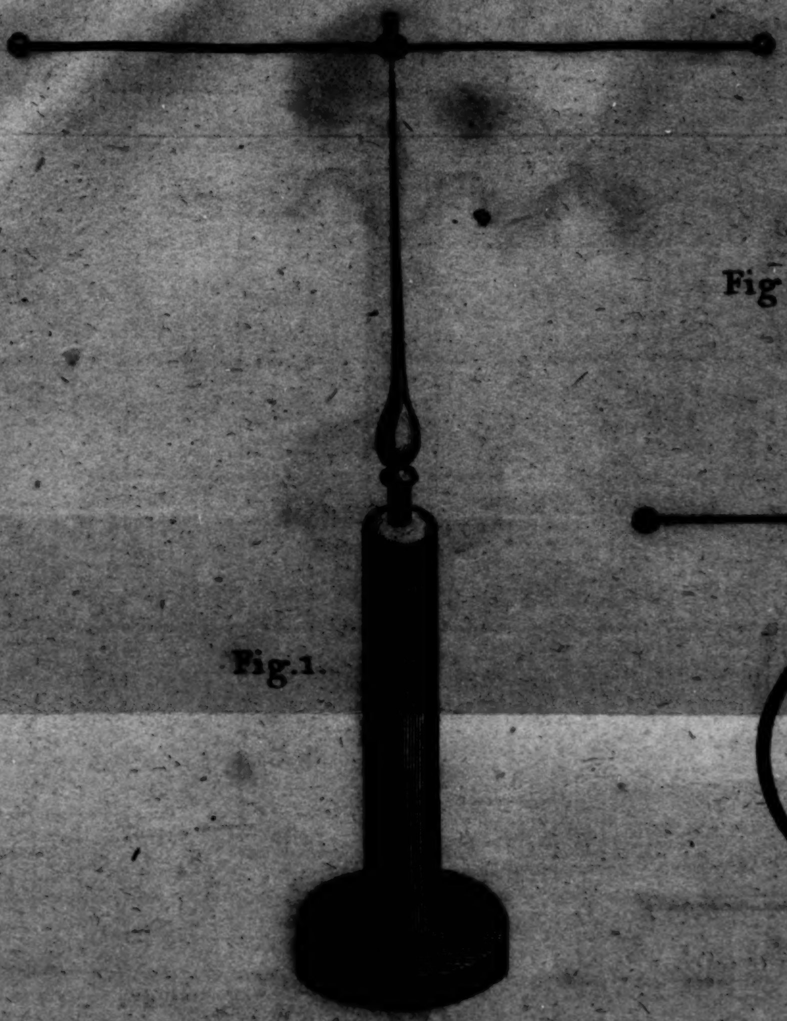

Fig. 1.

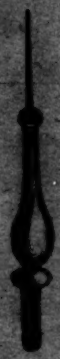

Fig. 2.

Fig. 3.

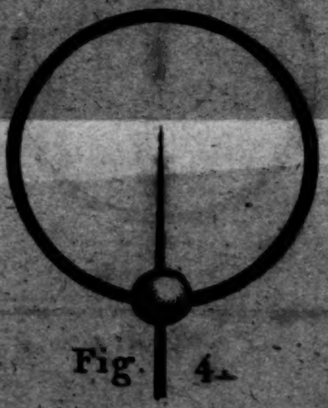

Fig. 4.

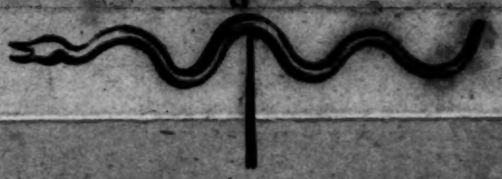

Fig. 6.

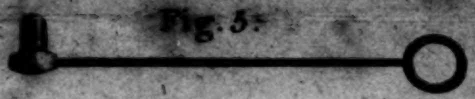

Fig. 5.

Fig. 7.

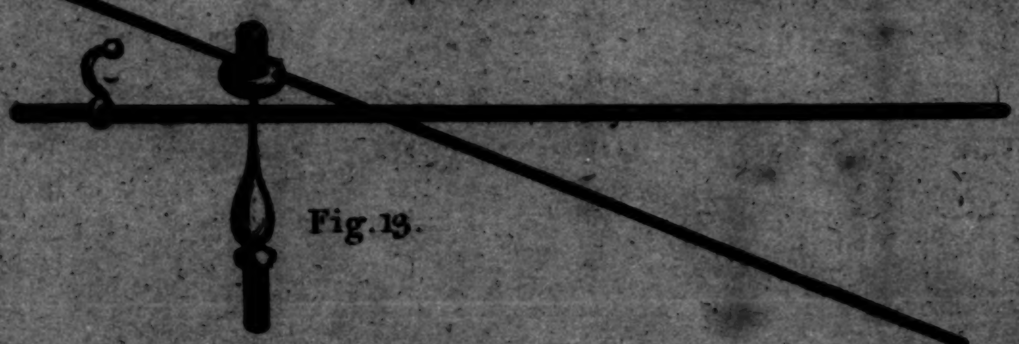

Fig. 13.

Jn. Lodge Sculp.